Card

FACILITY FORM 602

N65-86977
(ACCESSION NUMBER)

55
(PAGES)

CR-64192
(NASA CR OR TMX OR AD NUMBER)

(THRU)

None
(CODE)

(CATEGORY)

RE-ORDER NO. 65-335
APP. B

APPENDIX B

LINEAR SIGNAL/NOISE SUMMER

Submitted as part of the Final Report

for RF Test Console on JPL

Contract No. 950144

NAS 7-100

CONTRIBUTOR: J. L. Sundry

DATE:

September, 1964

WESTINGHOUSE DEFENSE AND SPACE CENTER

SURFACE DIVISION

ADVANCED DEVELOPMENT ENGINEERING

65-355
App. B

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

65-3??
ANY-?

LIST OF TABLES

65 33
APP. 5

I. GENERAL

The Linear Signal/Noise Summer as outlined in the JPL Design Specification is to function as an accurate power level moniter and control of signal power and noise power levels. By independently attenuating the signal power and noise power levels the Summer is to linearly mix them and thereby generate accurate and stable signal to noise ratios. The specification requirements for the Linear S/N Summer are:

S/N Dynamic Range	0 to 100db
Absolute Accuracy	+ .3db over 4 hour period
Signal Power Stability	$\pm$ .1db over 4 hour period
Noise Power Stability	+ .1db over 4 hour period
Noise Bandwidth	45 to 55 mc + .05 db
Noise Amplitudé	Linear up to 5σ
Power Monitor	Resolution better than .05db $\pm$ .1db uncertainty.

The Linear S/N Summer which has been built differs from the one outlined in the specification mainly in the Power Monitor. The Power Monitor incorporated serves not only as a device to monitor the signal and noise power levels but also as a feedback control on the noise source with the average signal power used as the reference. The results of the measurements of the S/N Summer meet the requirements as outlined in the specifications above.

The report herein contains the analysis and performance results of the Linear Signal/Noise Summer designed as per the requirements of JPL Design Specification No. GPG-15062-DSN. This report is subdivided into six major areas of design and test performance. These include, the noise source, the filter, the noise amplifier, the 50MC source and modulators, the power monitor and the overall system performance. A block diagram of this breakdown is shown in Figure 1.

6

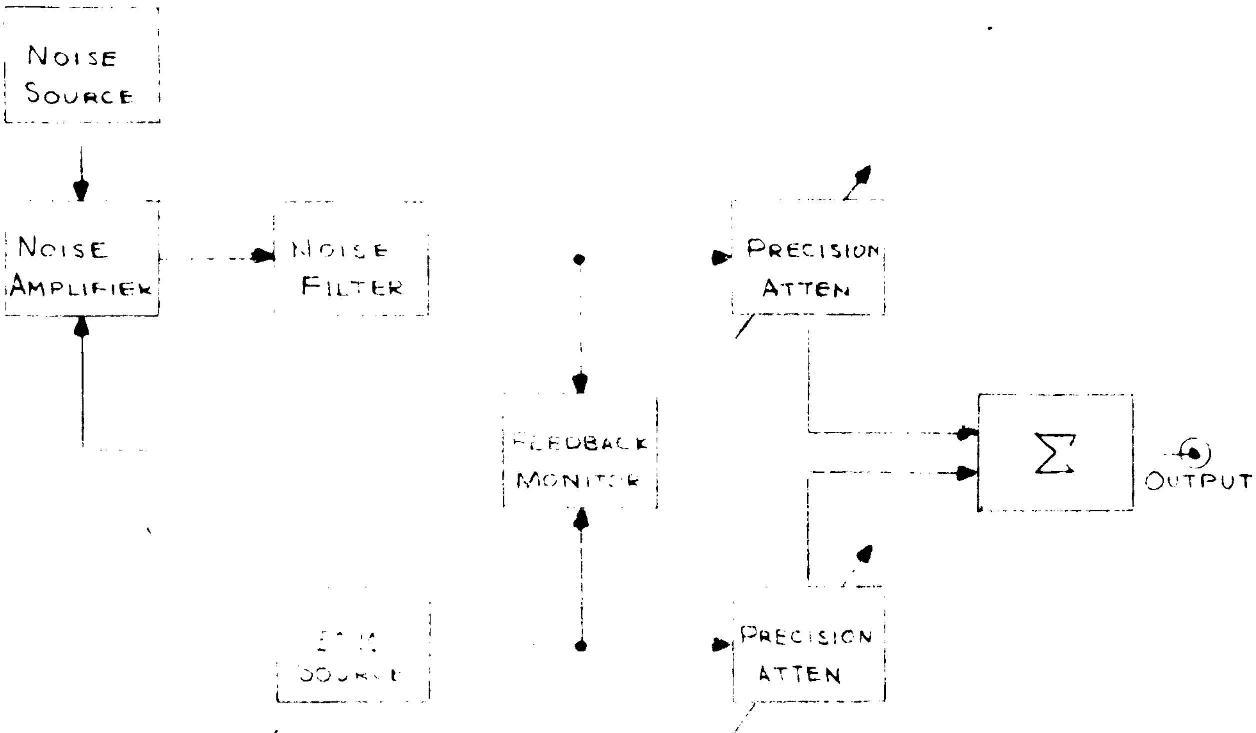


Figure 1. S/N [illegible]

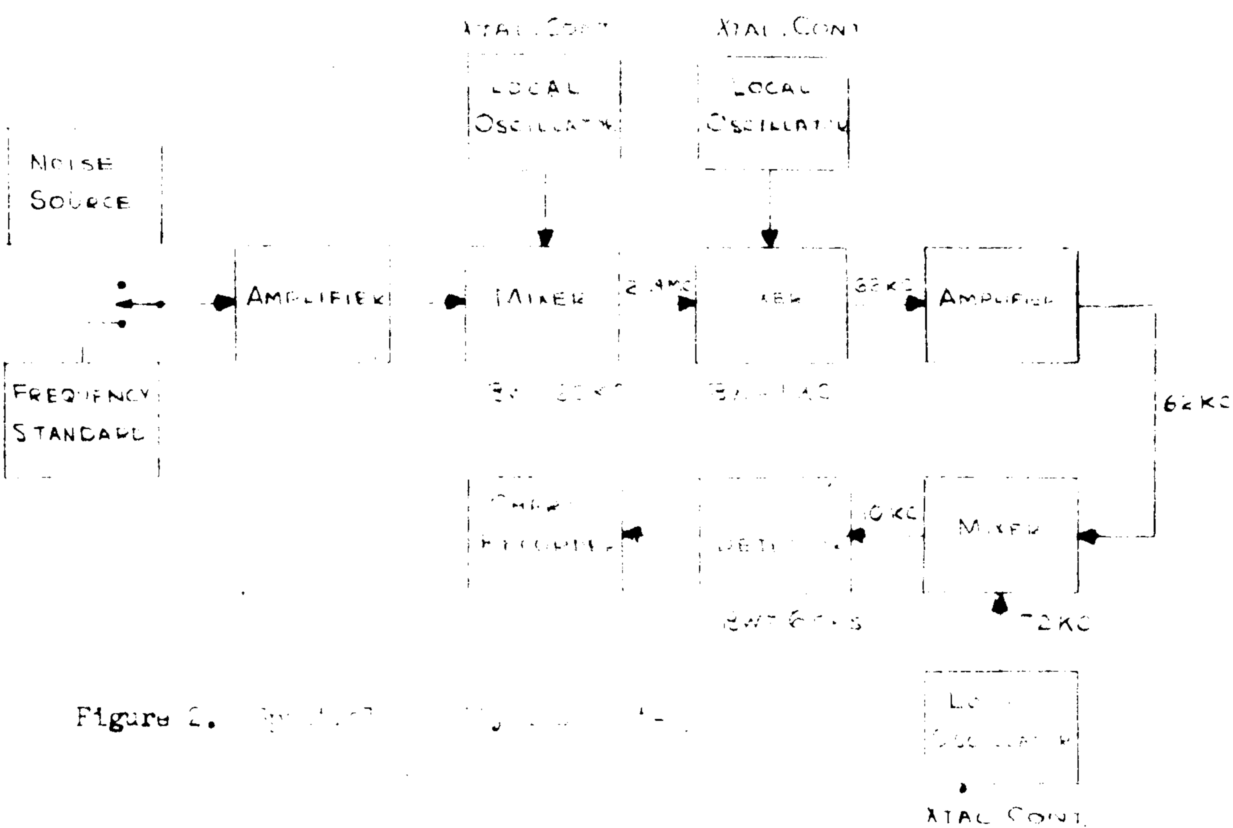


Figure 2. [illegible]

65-225 App

II. NOISE SOURCE (Rohde & Schwarz, Type SKTU)

After a survey of the commercial instrumentation market, Rhodes and Swartz was selected as the supplier of the noise source. Based on noise power spectral density test conducted by the vendor it was decided that the noise generator would meet the specification requirements. Using frequency translation techniques, the noise generator was tested first from 45 to 55 MC in 1MC steps using a 1 KC detection bandwidth. The noise source was then tested in 1 KC steps from 50.00 MC to 50.01 MC using a 200 cycle bandwidth and finally it was tested in 100 cps steps from 50.000 MC to 50.001 MC with a detection bandwidth of 6 cps. The test set-up for the 100 cps steps is shown in Figure 2. The plots of the test results are shown in Figure 3, 4, and 5.

From the results shown in Figure 5 it appears that the power density falls outside the required specification of $\pm$ .05db. The data is inconclusive in that an insufficient amount of time was alloted to acquire a measurement at any one frequency. In this test set-up, the detected output was recorded on a strip chart. After a given period of time the chart recording was graphically integrated to get the mean value for that frequency. The required measurement time necessary to insure 95% confidence with a $\pm$ .05db tolerance is approximately 16 hours for each frequency at this 6 cps bandwidth. Although it is not known exactly what time was alloted for this test it is known that the integration time was insufficient. This was not a problem at the larger bandwidths for more points could be sampled in a shorter period of time. Therefore, at the higher bandwidths the readings were more of an

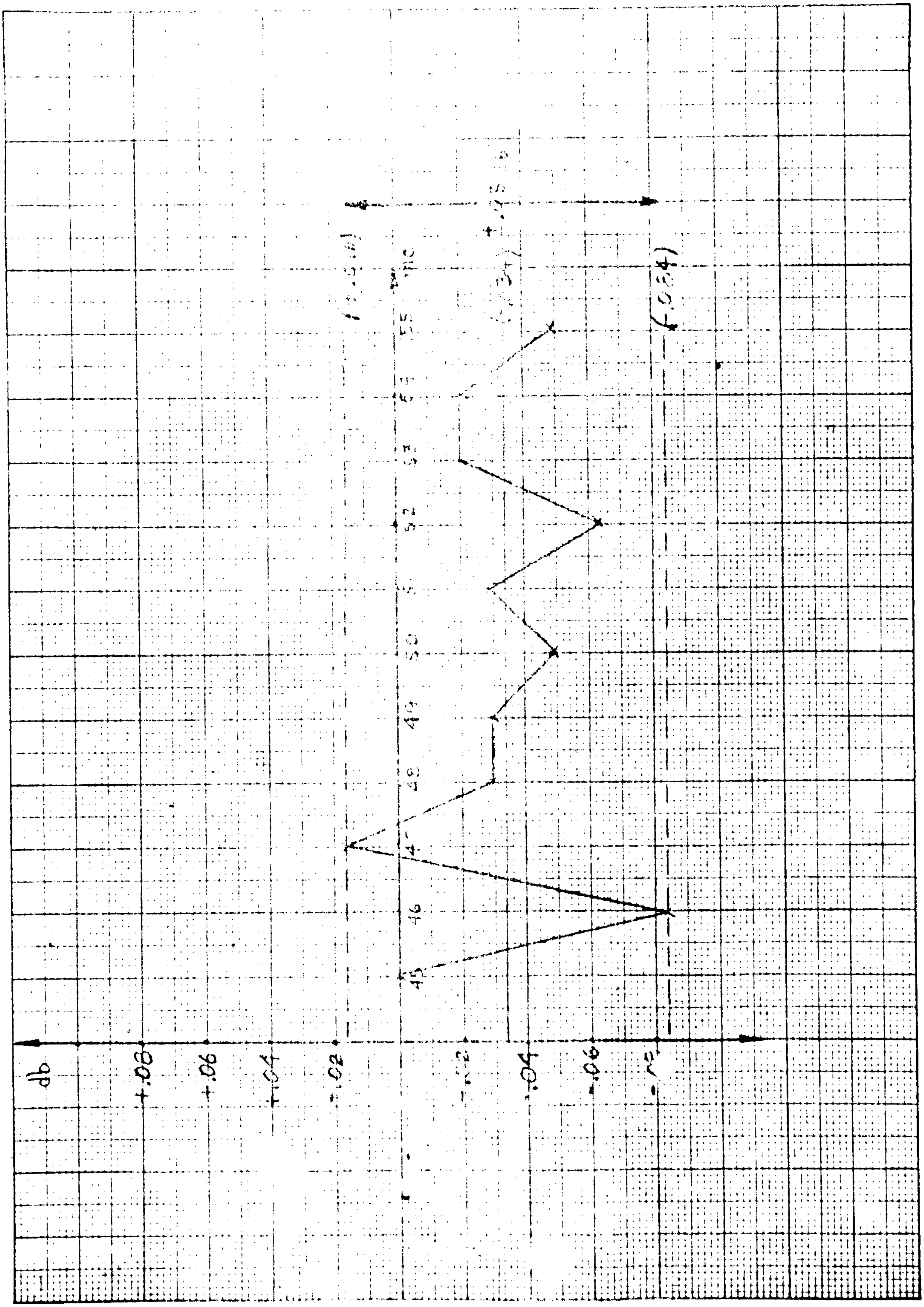


Figure 3 Spectral Density 45 to 55 KC (1 KC steps)

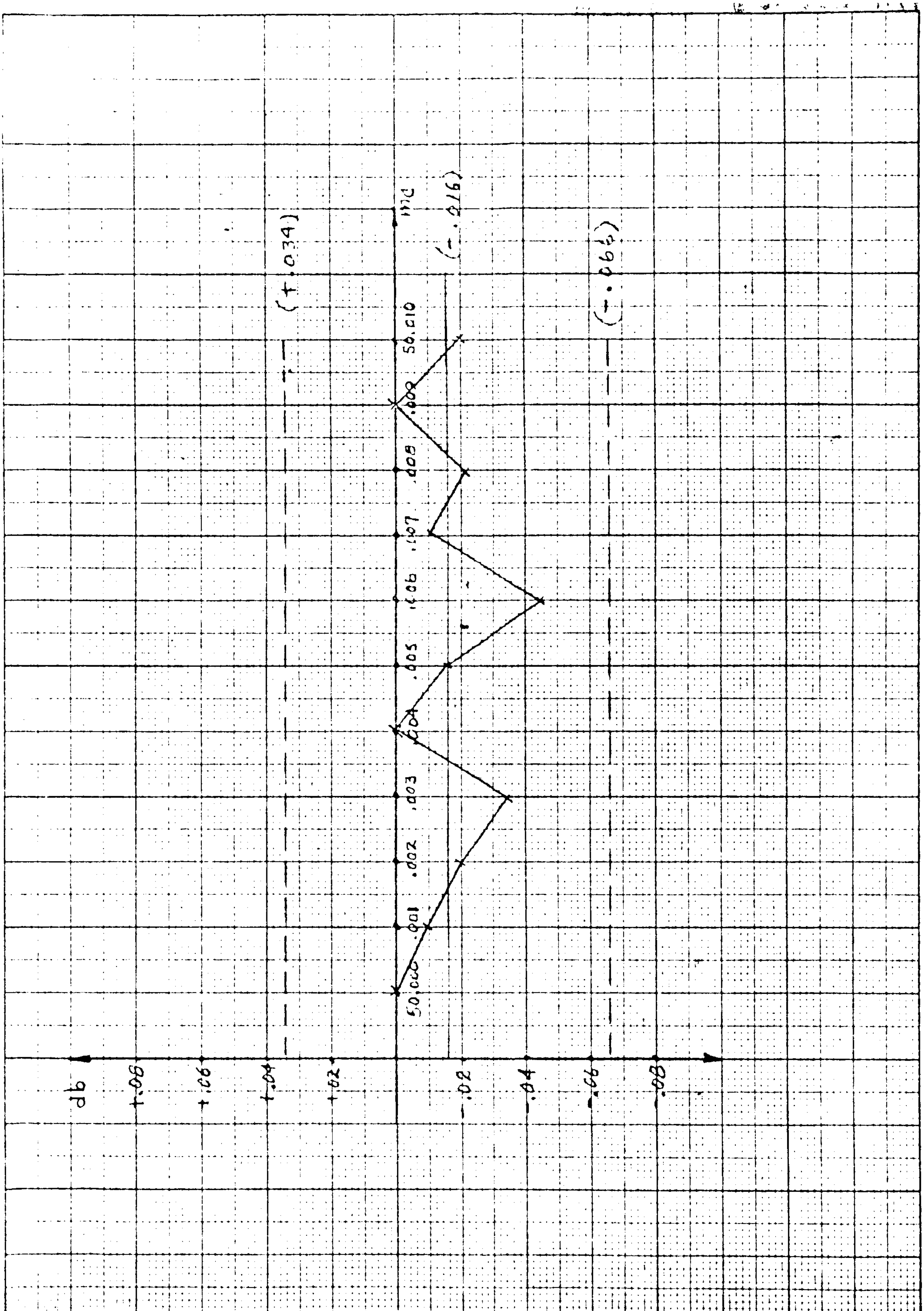


Figure 4 Spectral Density 50,000 to 50,010 MC (1 KC steps)

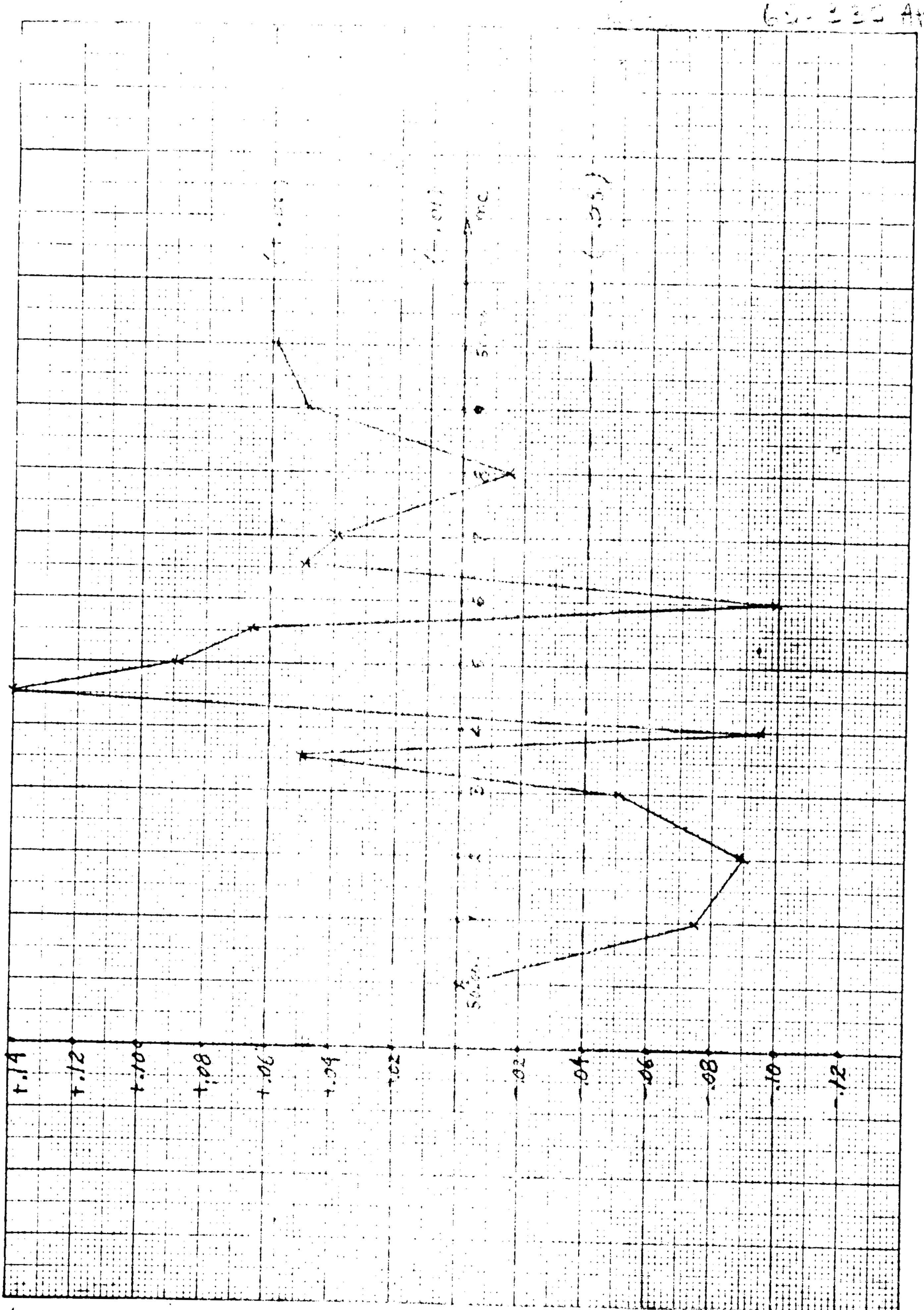


Figure 5 Spectral density [illegible] to 50,0010 MC (100 cps steps)

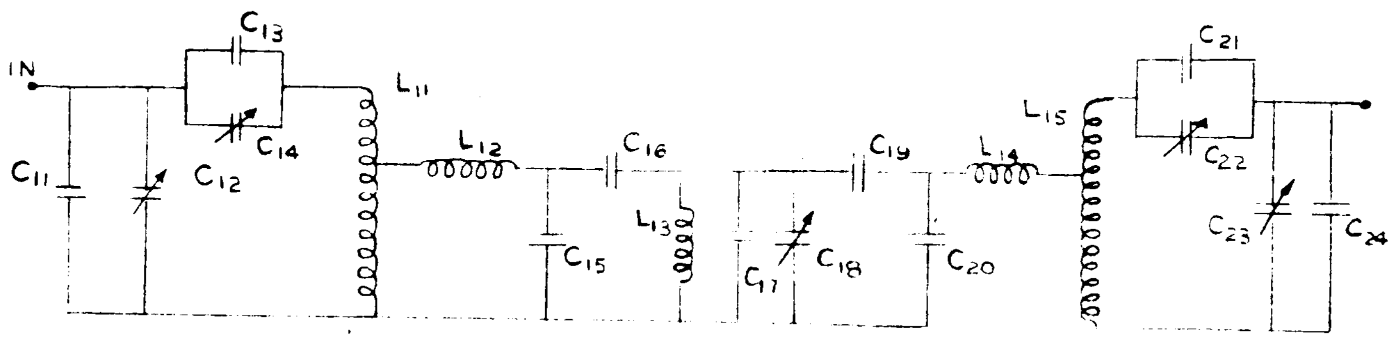
average power density plot and based on the results of these two tests (i.e. 1 KC and 200 cps bandwidths) and the fact that the readings of the 6 cps bandwidth were spread about zero, the generator was selected as the noise source. It was decided that the spectral density would be tested at the Summer output taking the Linear S/N Summer as an integral system.

12

I.I. NOISE FILTER

Specifications for the noise filter were generated based on paragraph 3.5.3 of the JPL Design Specification No. GPG-1?062-DSN. A noise filter flat within ± .05db from 45 MC to 55 MC with a noise bandwidth of 10 MC is unrealizable. It was therefore decided to design a passband of 46 to 54 MC with a flatness of ± .05db and strive to achieve a noise bandwidth as close as possible to 10 MC. The above parameters along with a VSWR of 1.10, an impedance of 50 ohms resistive and a insertion loss of 1db maximum, were programmed into a computer. The results indicated a 5 pole filter would yield a 3db BW of 11.5 MC with an impedance of 1 ohm reactive and 50 ohms resistive at the input and output. The principle problem was the practical realization of the coil accuracies. Using transformation techniques the resultant filter shown in Figure 6 was constructed.

The VSWR of the filter was checked using a reflectmeter techniques and comparison with a load of known VSWR and found to be within the 1.10 specification. The insertion loss was measured to be .85db. The frequency response was checked in two phases. The passband response from 45 MC to 55 MC was checked on the high resolution dual channel system and the out of band response was checked using a series substitution technique. These test set ups are shown in Figure 7. The results of these two tests are shown on the frequency response plots of Figures 8 and 9. From these results it can be seen that the filter is slightly off-set from 50 MC at 4?.8 MC with a noise bandwidth of 15.05 MC and has a pass band response of ± .05db over an 8 MC



$L_{11} = L_{15}$ = 0.25 μh (9 Turns of # 6 Bus on LS 6 Form; No Slug; Tap at 5 Turns from Ground)

$L_{12} = L_{14}$ = 1.0 μh (12½ Turns of #26 Form.var Wire on LS-6 Form; No Slug)

L_{13} = 0.068 μh (4 Turns of # 16 Bus Wire on LS 6 Form)

$C_{11} = C_{24}$ = 50 μμf Duramica, DM-15 Case, ± 2%

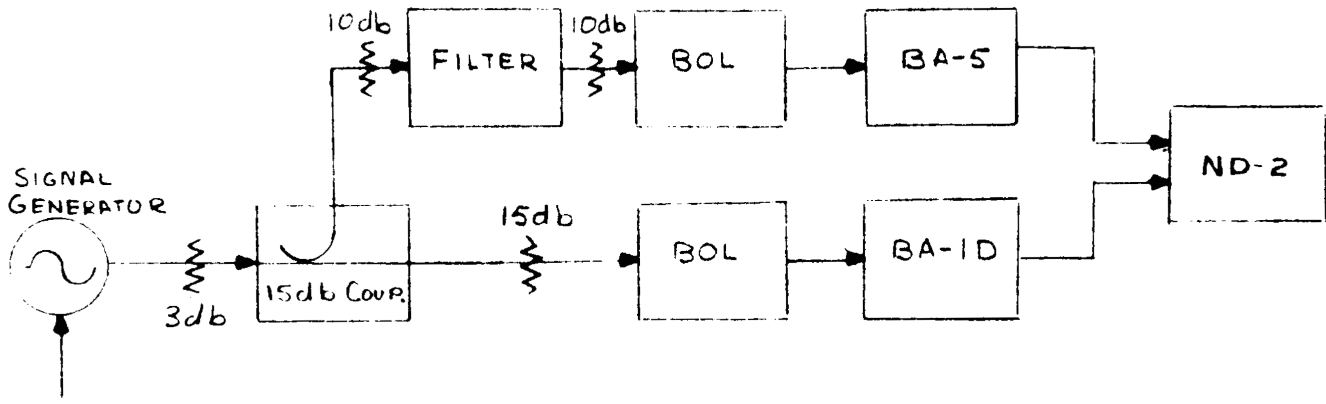
$C_{18} = C_{14} = C_{12} = C_{23} = C_{22}$ = 8-50 μμf Erie Trimmer (N-750)

$C_{13} = C_{21}$ = 36 μμf Duramica DM-15; ± 2%

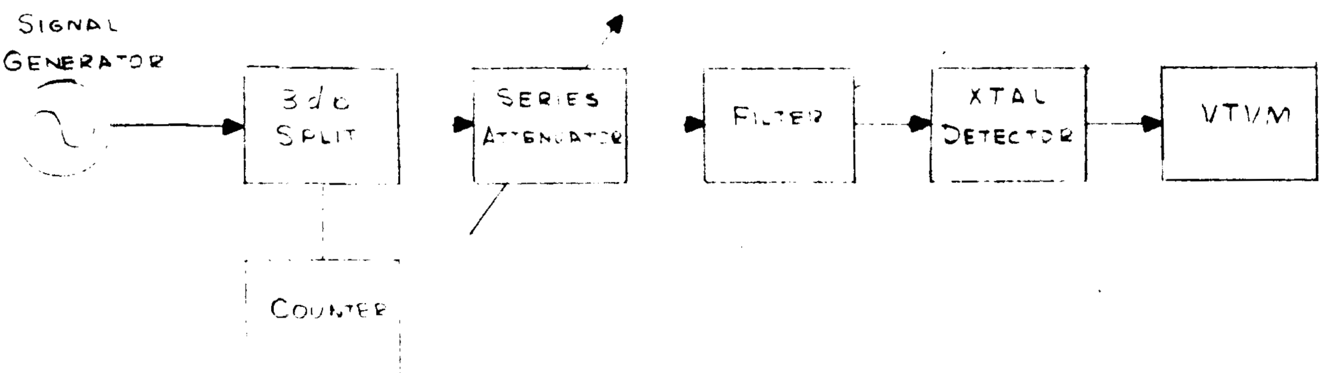
$C_{15} = C_{16} = C_{19} = C_{20}$ = 0.8 - 8.5 μμf, JFD VC-20

C_{17} = 100 μμf, Duramica, DM-15, ± 2%

Figure 6. [illegible] Schematic



PASSBAND RESPONSE TEST SET-UP (7A.)



OUT OF BAND RESPONSE TEST SET-UP (7B.)

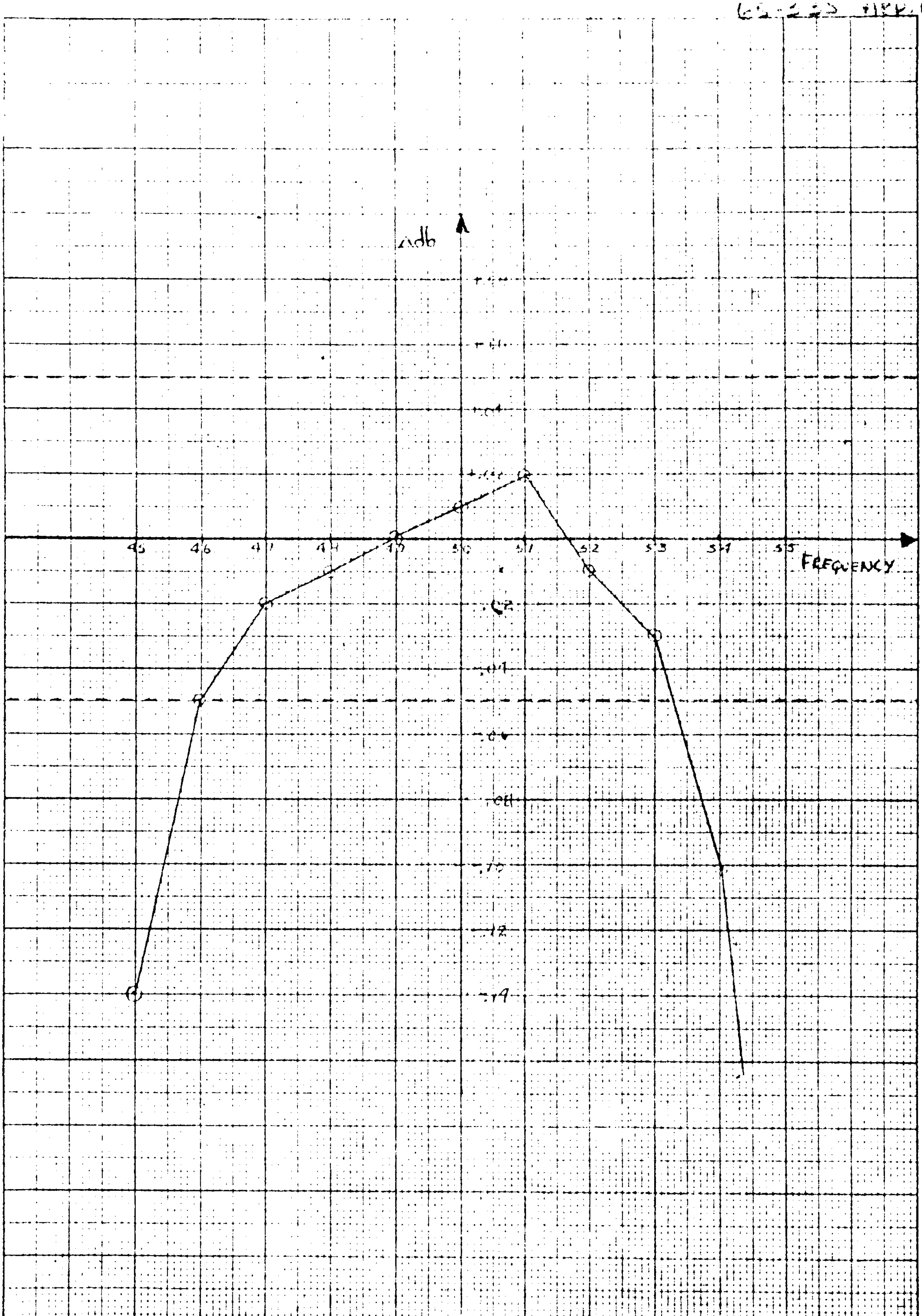
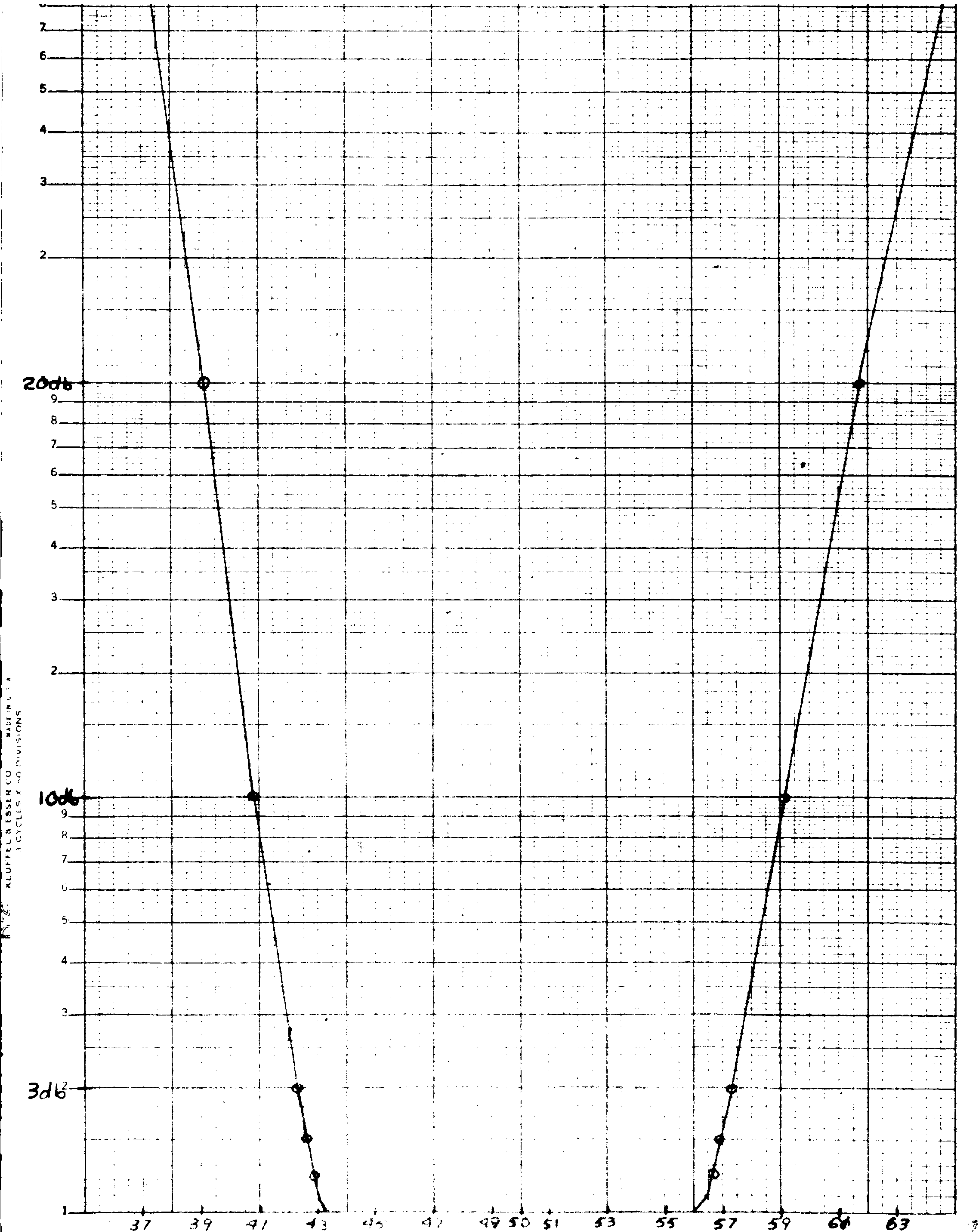


Figure 8. Noise Filter Passband Response (Figure 7A)


20db
10db
3db
37
39
41
43
50
51
53
55
57
59
63
KEUFFEL & ESSER CO.

range from 45.6 [illegible] to 53.6 [illegible]. The noise bandwidth was determined to be 15.[illegible] [illegible] by [illegible] integration of an enlarged amplitude response.

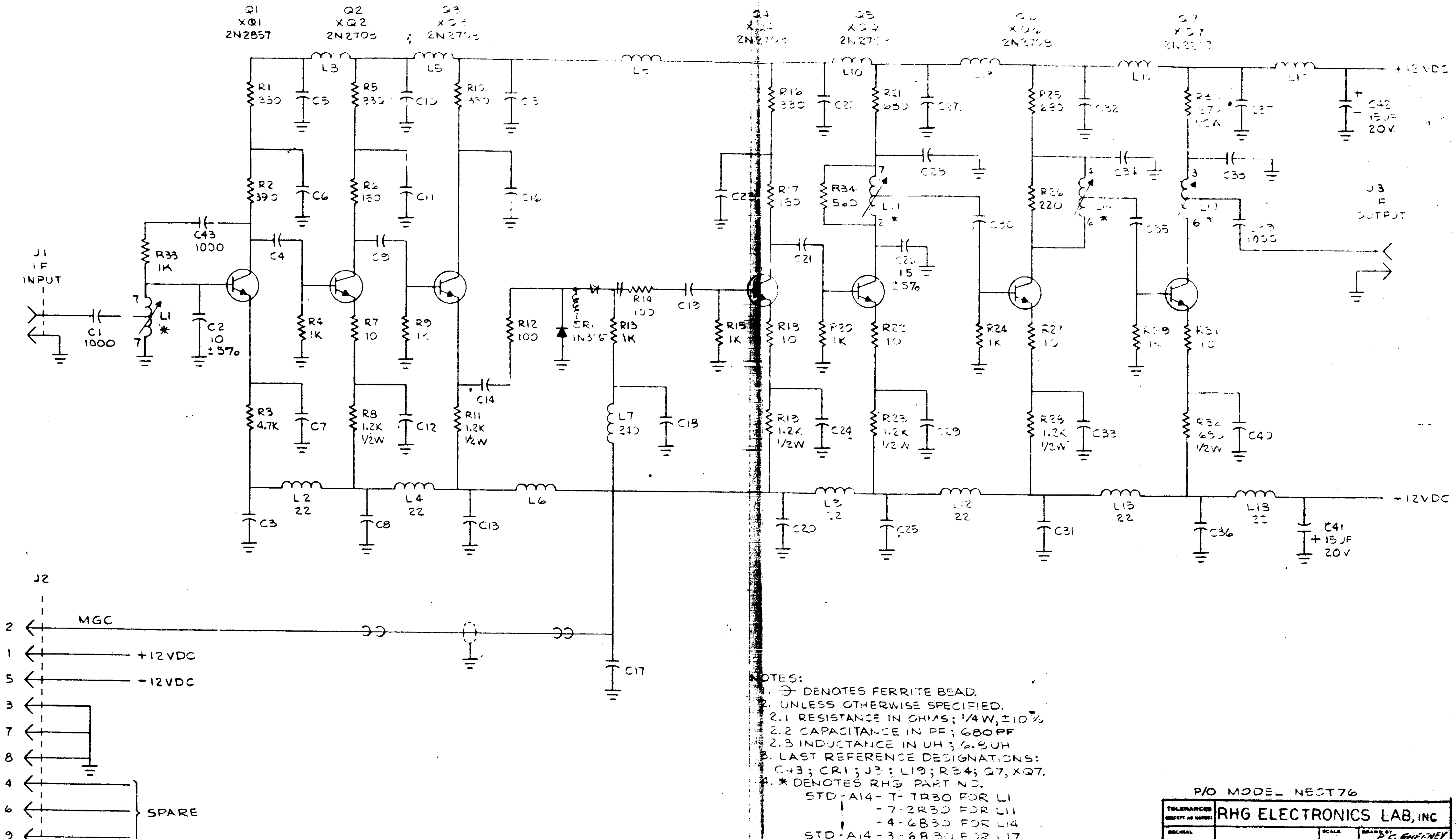
IV. NOISE AMPLIFIER

The noise amplifier was purchased from RHG Electronics based on the best competitive bid meeting the specification requirements.

The amplifier was made in two chassis. One is six stages of preamplification incorporating three broadly tuned stages and three non-tuned stages with a diode AGC circuit between them. The second chassis is three broadly tuned stages of power amplification with 3 poles centered at 50, 44, and 56 MC. Schematics of the noise amplifier are shown in Figures 10 and 11.

Frequency response, intermodulation, linearity and gain tests were conducted on the amplifier. The amplifier measured a noise figure of 3db and a maximum gain of 115db. Due to matching problems which upset the frequency response, the vendor supplied the noise amplifier with a 3db pad between the preamplifier and the power amplifier, which reduced the maximum gain to 112db.

Since the operation of the amplifier was only meaningful when operated into its proper load the amplifier/filter was tested as an integral unit. The combination was first tested using swept frequency techniques and found to be out of specification. The problem was the mismatch between the amplifier and the filter. The best match and frequency response was achieved with a 10db pad between the amplifier and the filter. The combination was then tested using the point by point technique on the Dual Channel system. The test set-up is shown in Figure 12. In all the noise amplifier tests unless otherwise stated, the AGC was zener regulated at approximately 1.0 MA



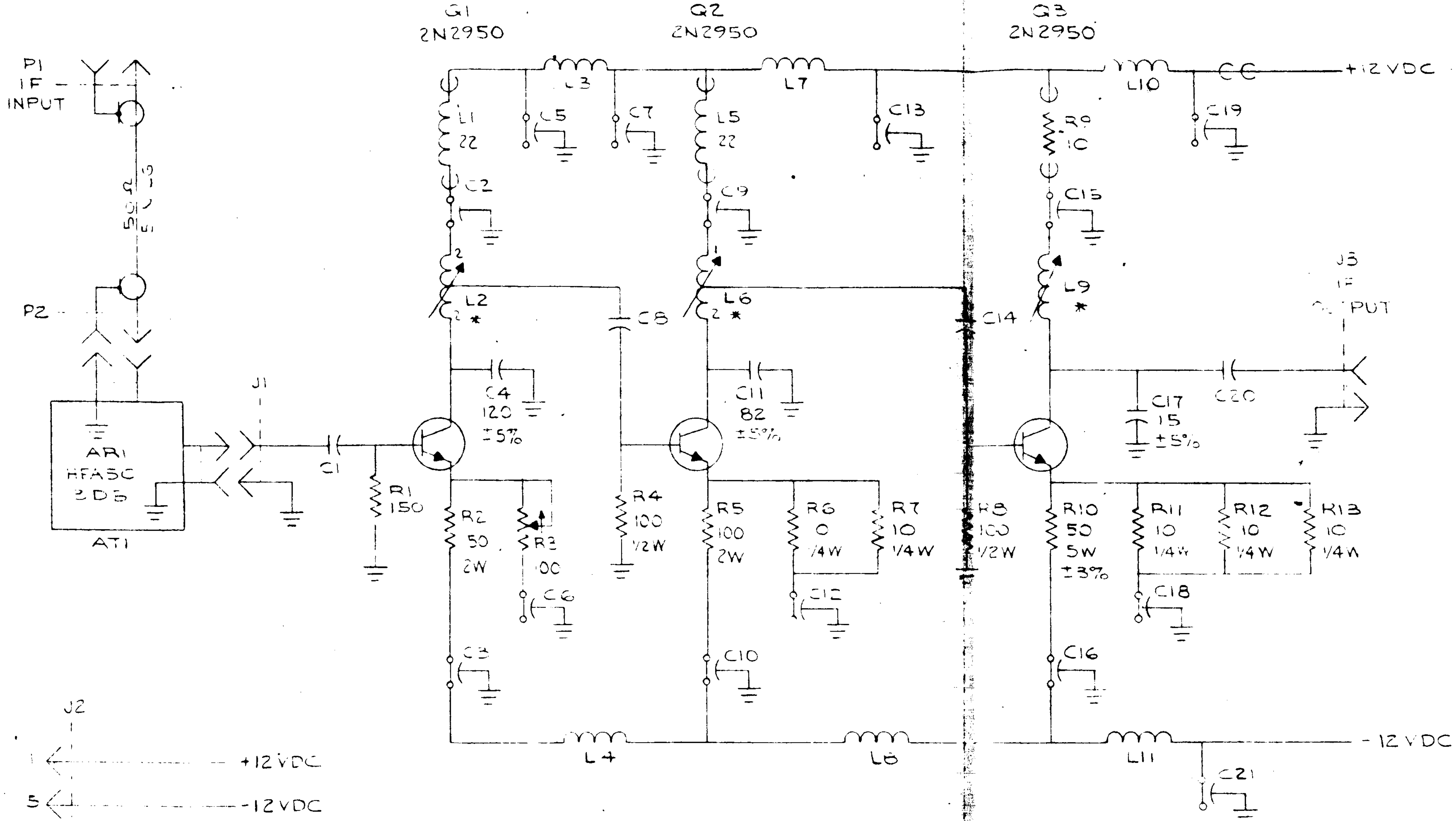
NOTES:
1. ⊃ DENOTES FERRITE BEAD.
2. UNLESS OTHERWISE SPECIFIED.
2.1 RESISTANCE IN OHMS; 1/4 W, ±10%
2.2 CAPACITANCE IN PF; 680PF
2.3 INDUCTANCE IN UH; 6.8UH
3. LAST REFERENCE DESIGNATIONS:
C43; CR1; J3; L19; R34; Q7, XQ7.
4. * DENOTES RHG PART NO.
STD-A14-7-TR30 FOR L1
-7-2R30 FOR L11
-4-6B30 FOR L14
STD-A14-3-6B30 FOR L17

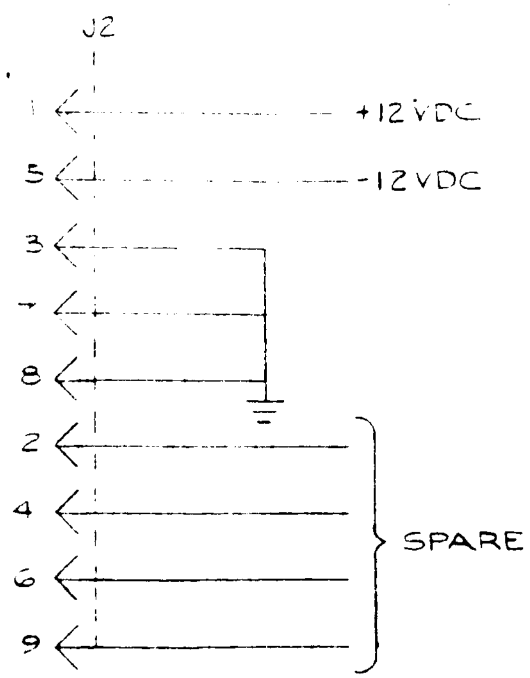
P/O MODEL NECT76

TOLERANCES (EXCEPT AS NOTED)	RHG ELECTRONICS LAB, INC		
DECIMAL ±		SCALE —	DRAWN BY P. C. GAFFNEY; APPROVED BY
FRACTIONAL ±	TITLE SCHEMATIC, PREAMPLIFIER		
ANGULAR ±	DATE 6-9-64	DRAWING NUMBER 1-612-1A1	

FIGURE 10 PREAMPLIFIER SCHEMATIC

65-335 APP. E





NOTES:
1. UNLESS OTHERWISE SPECIFIED:
1.1 RESISTANCE IN OHMS ±10%.
1.2 CAPACITANCE IN PF ...000 PF.
1.3 INDUCTANCE IN UH; 6... UH
2. LAST REFERENCE DESIGNATIONS
C21; J3; L12; R13; Q3; P2; AT1.
3. * DENOTES RHG PART ...
STD-A14-...W26 FOR L...
A14-1-2R26 FOR L...
STD-A11-5R... FOR L9.
4. —⊂— DENOTES FERRITE BEAD

P/O MODEL N50T76

TOLERANCES (EXCEPT AS NOTED)	RHG ELECTRONICS LAB, INC			
DECIMAL ± ——	C		SCALE NONE	DRAWN BY E. J. Rumpf / APPROVED BY
FRACTIONAL ± ——	TITLE SCHEMATIC, POWER AMPLIFIER			
ANGULAR ± ——	DATE 6-10-64	DRAWING NUMBER 1-612-2A1		

FIGURE 11 POWER AMPLIFIER SCHEMATIC

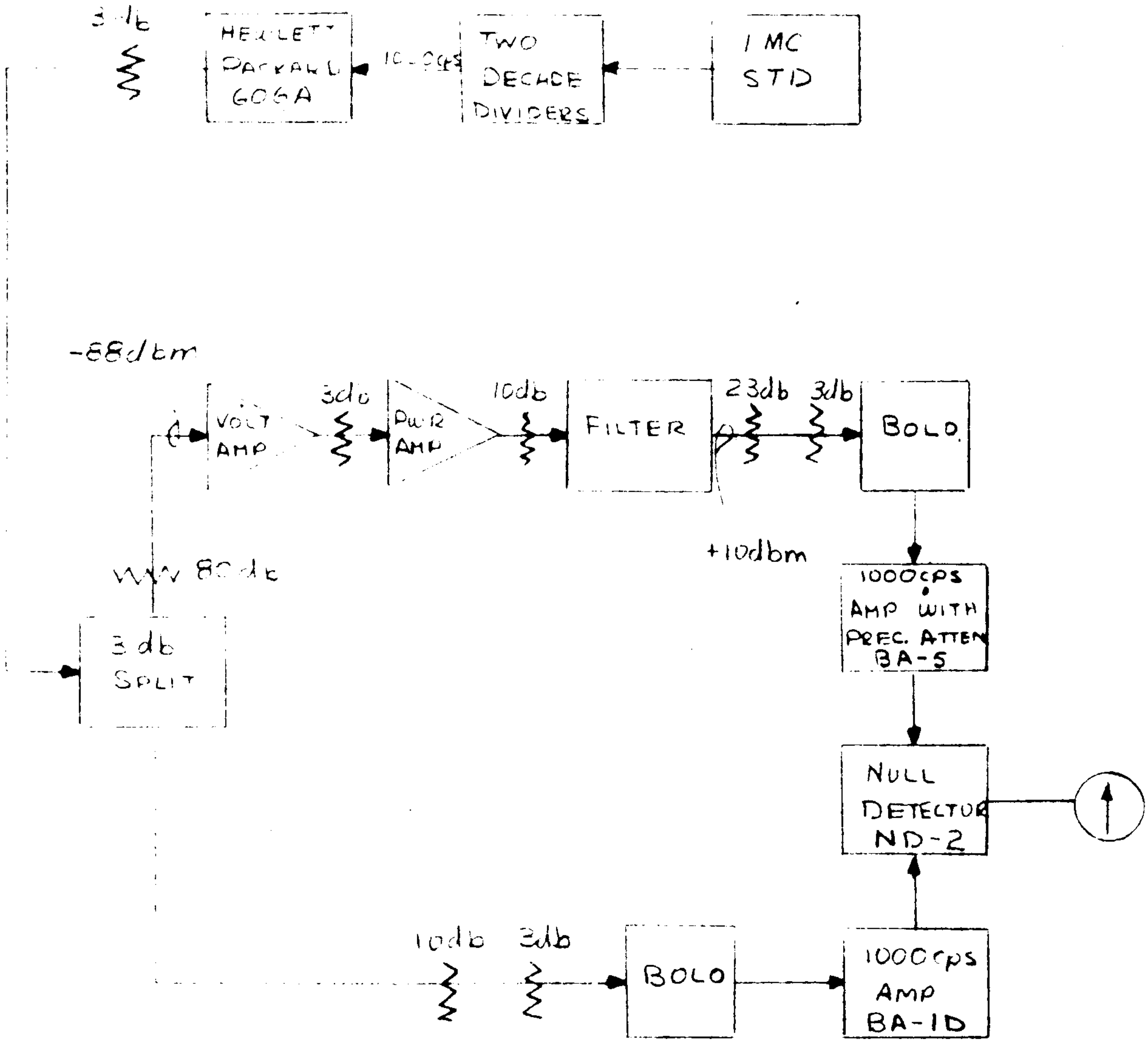


Figure 1[illegible]. Noise Amplifier/Filter Frequency Response Test Set-up

65-335
APP. E

which is 3db down from maximum gain and approximately the operating point used in the system operation. After retuning the power stage of the noise amplifier, the Noise Amplifier/Filter frequency response was measured to be flat within ± .05db from 44.6 to 53.6 MC. These measurement results were repeated several times within .02db. The result of this frequency response test is shown in Figure 13.

The frequency response of the Noise Amplifier/Filter was also checked in an oven at 35°C, 40°C and 45°C and found to be quite dependent on temperature. The results of this test are shown in Figure 14. From the results of this test it was decided the Noise Amplifier/Filter in its final form would be placed in a temperature controlled oven.

The error due to intermodulation in the Noise Amplifier may be analyzed by representing the transfer by a power series. It was found that the third-order harmonic intermodulation of $(2f_1 - f_2)$ had resulting products which fall within the passband and constitute an error in the true amplifier noise power. This was tested using a two tone test at rated output, 6db above rated output and 6db below rated output. As shown in Table I, the passband intermodulation power contribution is less than 1/1000 of the fundamental.

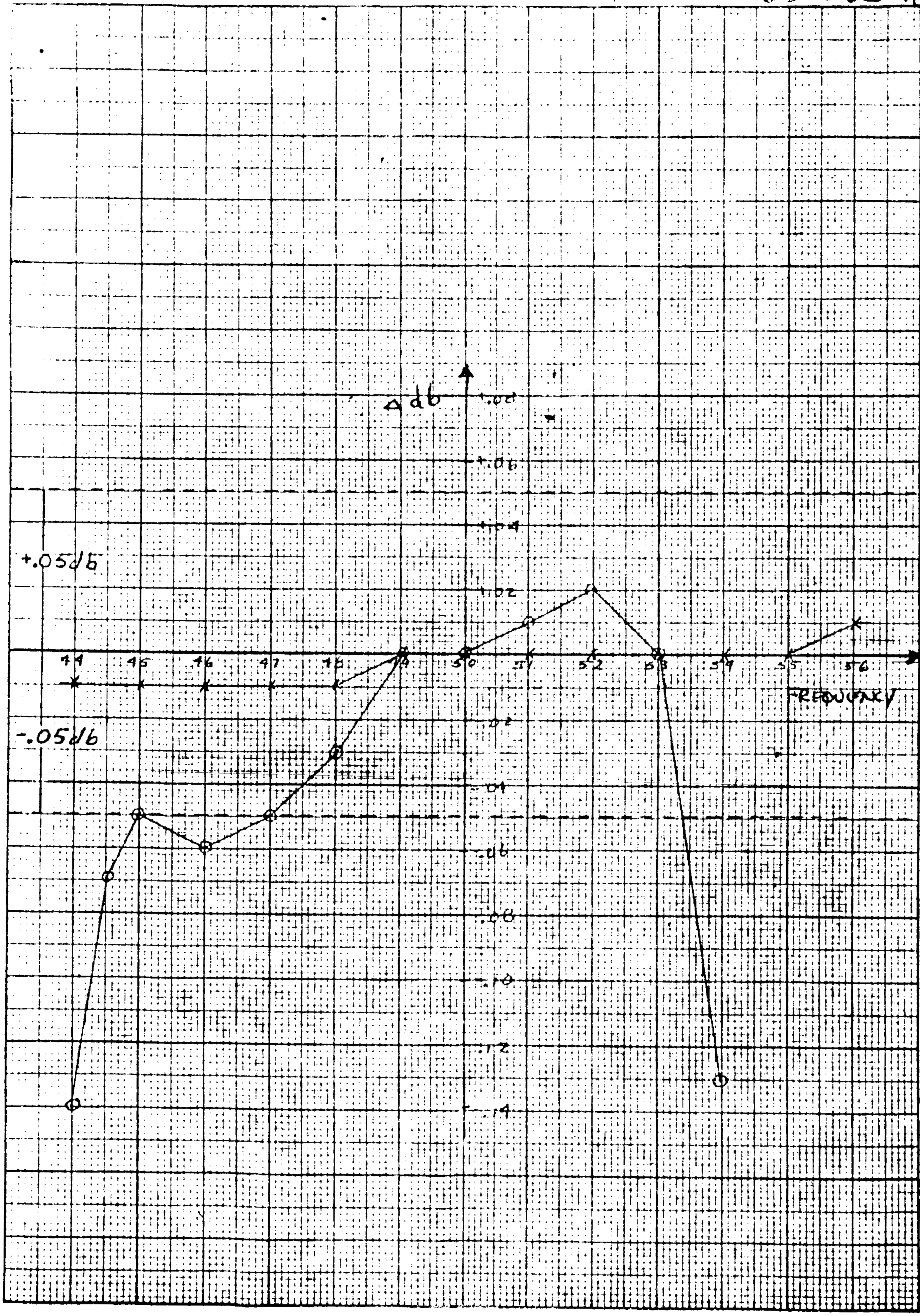


Figure 13. Noise Amplifier Point by Point Freq. Response

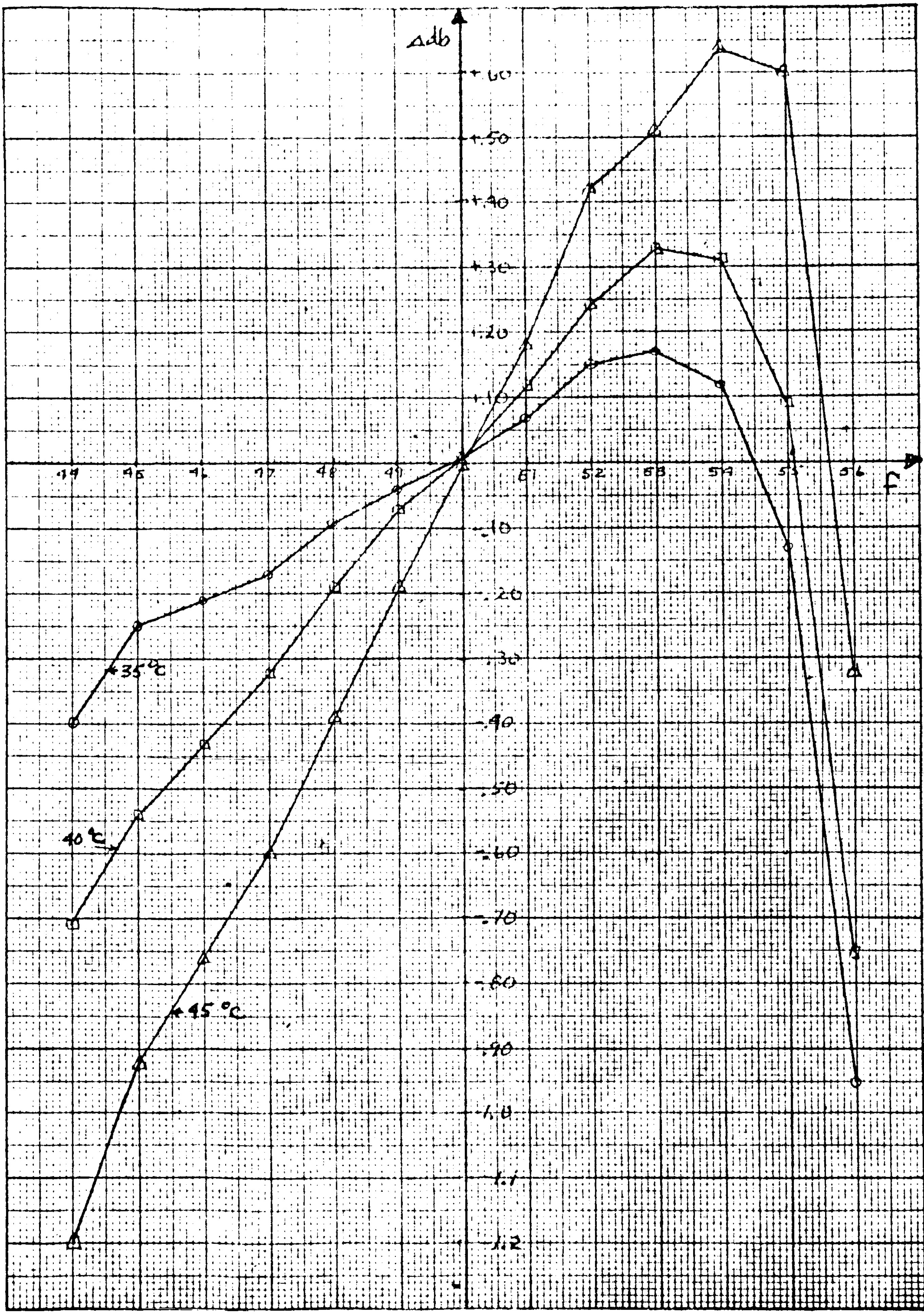


Figure 14. Noise Amplifier Frequency Response vs. Temperature

Input Frequency f1 = 50 MC at +7 dbm Output

Input Frequency f2 = 44 MC at +7 dbm Output

(2f1 - f2) = 56 MC

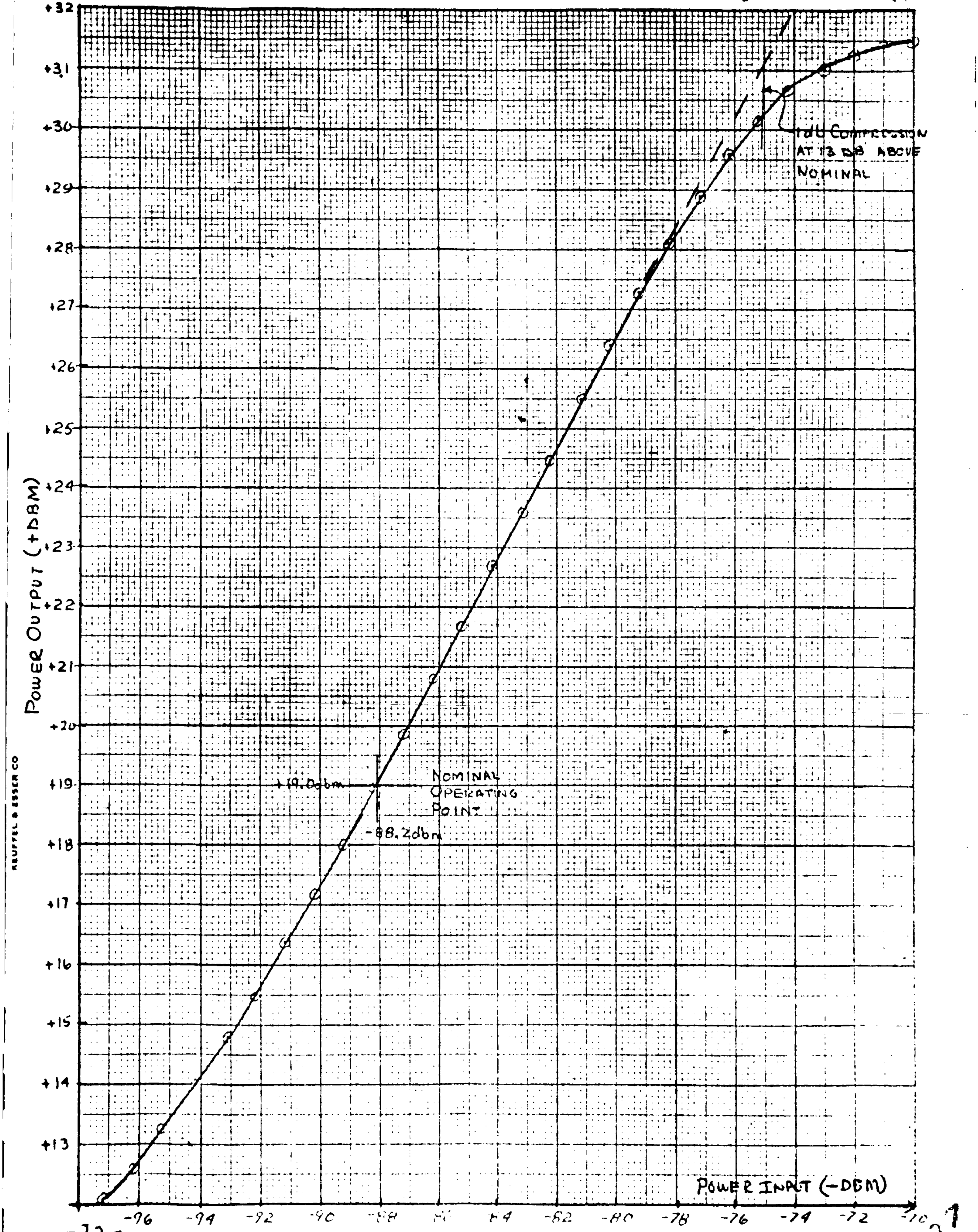
Nominal Output +10 dbm

	44 MC	50 MC	56 MC
6db Above Nominal	Ref.	Ref.	-32db
Nominal	Ref.	Ref.	-45db
6db Below Nominal	Ref.	Ref.	-57db

Table I. Noise Amplifier Intermodulation Test Results

The Noise Amplifier power transfer was tested to get a measure of the linearity. The $\frac{P_o}{P_{in}}$ transfer is shown in Figure 15. The regions of interest are the operating point which is very linear and the saturation level which shows a 1db compression up to 13db above the nominal operating point.

65-335



1dB Compression
At 13 dB Above
Nominal
Nominal
Operating
Point
+19.0dbm
-88.2dbm
Power Output (+DBM)
Power Input (-DBM)
+32
+31
+30
+29
+28
+27
+26
+25
+24
+23
+22
+21
+20
+19
+18
+17
+16
+15
+14
+13
-96
-94
-92
-90
-88
-84
-82
-80
-78
-76
-74
-72
-70
Keuffel & Esser Co

V. 50 MC SOURCE AND MODULATORS

The S/N Summer signal source is an unmodulated 50 MC carrier. The short and long term stability of the 50 MC source is of considerable importance as applied to the transmitter/receiver pair. The details of these characteristics and the steps taken to achieve suitable stability characteristics are discussed in the P. M. Receiver Study. However, as applied to the S/N Summer the 50 MC source is simply an angle modulated carrier with stable power characteristics and low spurious levels. The noise source is referenced to the signal source such that changes in the signal source is not reflected as a change in signal to noise ratio but rather as a change in absolute signal and noise power.

The 1 MC Standard was patterened after an existing design that was developed to exhibit extremely low short term instability. The source includes a proportional temperature controlled fundamental crystal ($Q = 3.0\ 10^{+6}$). Further, the crystal drive is controlled by an AGC loop and the oscillator is isolated from the load by suitable buffers. The schematic diagram of this unit is indicated in Figure 16.

The 1 MC source is multiplied to 50 MC by the following frequency multiplication steps X5, X5, X2. The 1 to 5 MC multiplier is packaged in one module and the 5 to 50 MC (X5, X2) is packaged in a second unit. The multipliers were patterned after an existing Westinghouse design that was developed to yield low short term instability and acceptable spurious rejection. The design details

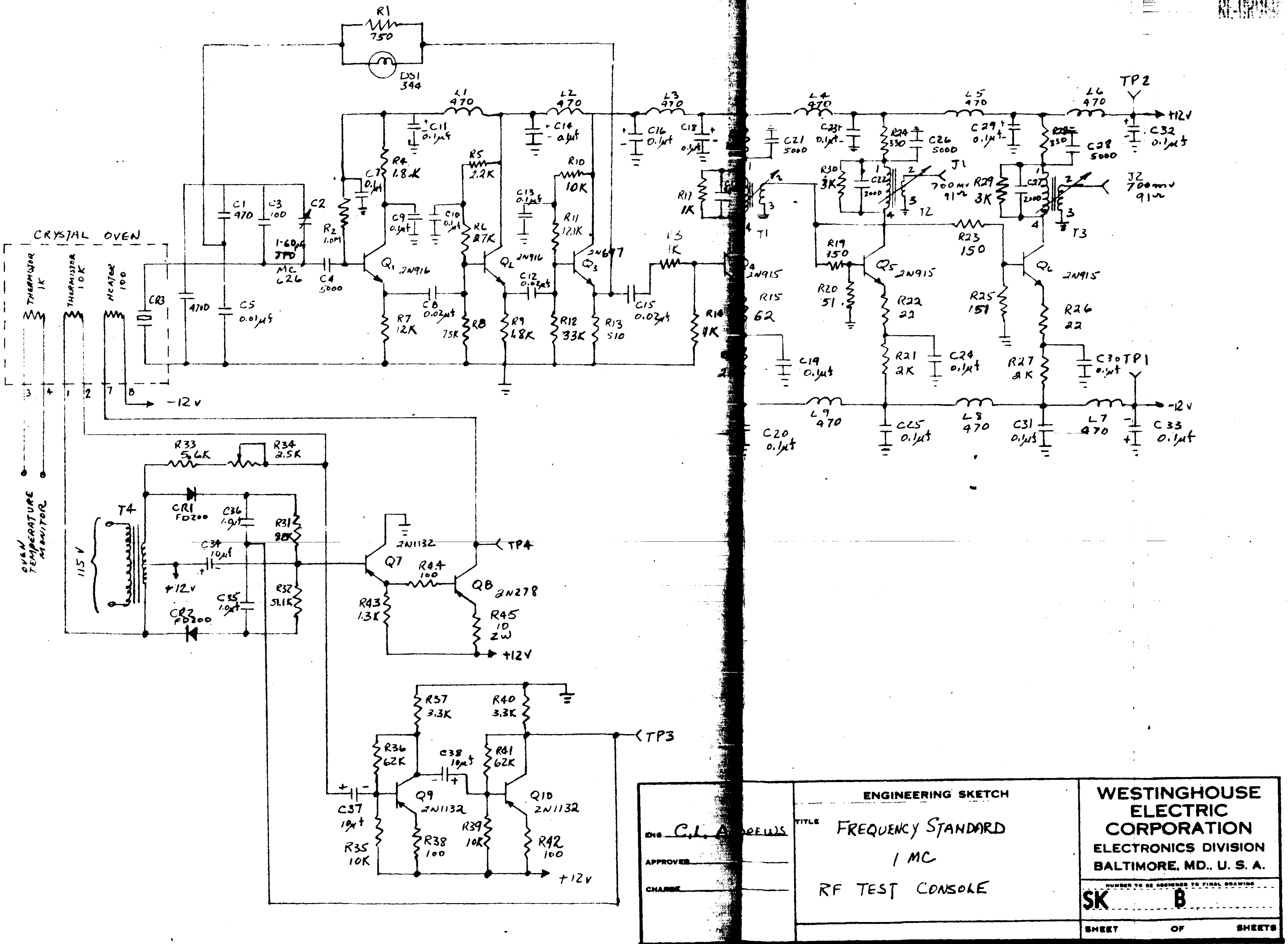


FIGURE 16 FREQUENCY STANDARD SCHEMATIC

are included in the MM Receiver study. The spurious levels relative to the unmodulated carrier are listed in Tables II and III. The long term stability of the 50 MC source measured 7.5 parts in 10^{+8} in 19 hours over a temperature range of $\Delta T = 20^\circ C$ centered on $25^\circ C$. The schematic diagrams of each multiplier in indicated in Figures 17 and 18.

The signal and noise are chopped at 1000 cps. After detection in the bolometer, the signals are amplifier in narrow band 1000 cps amplifies thus requiring very accurate and stable 1000 cps signals. This accuracy and frequency stability is achieved through frequency division from the 1 MC Standard. A block diagram of this Digital Divider is shown in Figure 19. The Linear S/N Summer requires two 1000 cps drive signals for the feedback monitor and two driver signals are required in the test measurement system.

The 1000 cps drive signal from the Digital Driver alternately short and open circuit a diode in series with the center conductor of each transmission line. The RF power incident on the diode modulator is reflected when the diode is open circuited due to the high forward impedance and is transmitted through the diode when the diode is short circuited. A schematic of the diode modulator is shown in Figure 20. High pass filters are used on the input and output of the diode modulator to attenuate 1000 cps currents and low pass filters are cascaded on the driver line to isolate the driver from the RF circuitry.

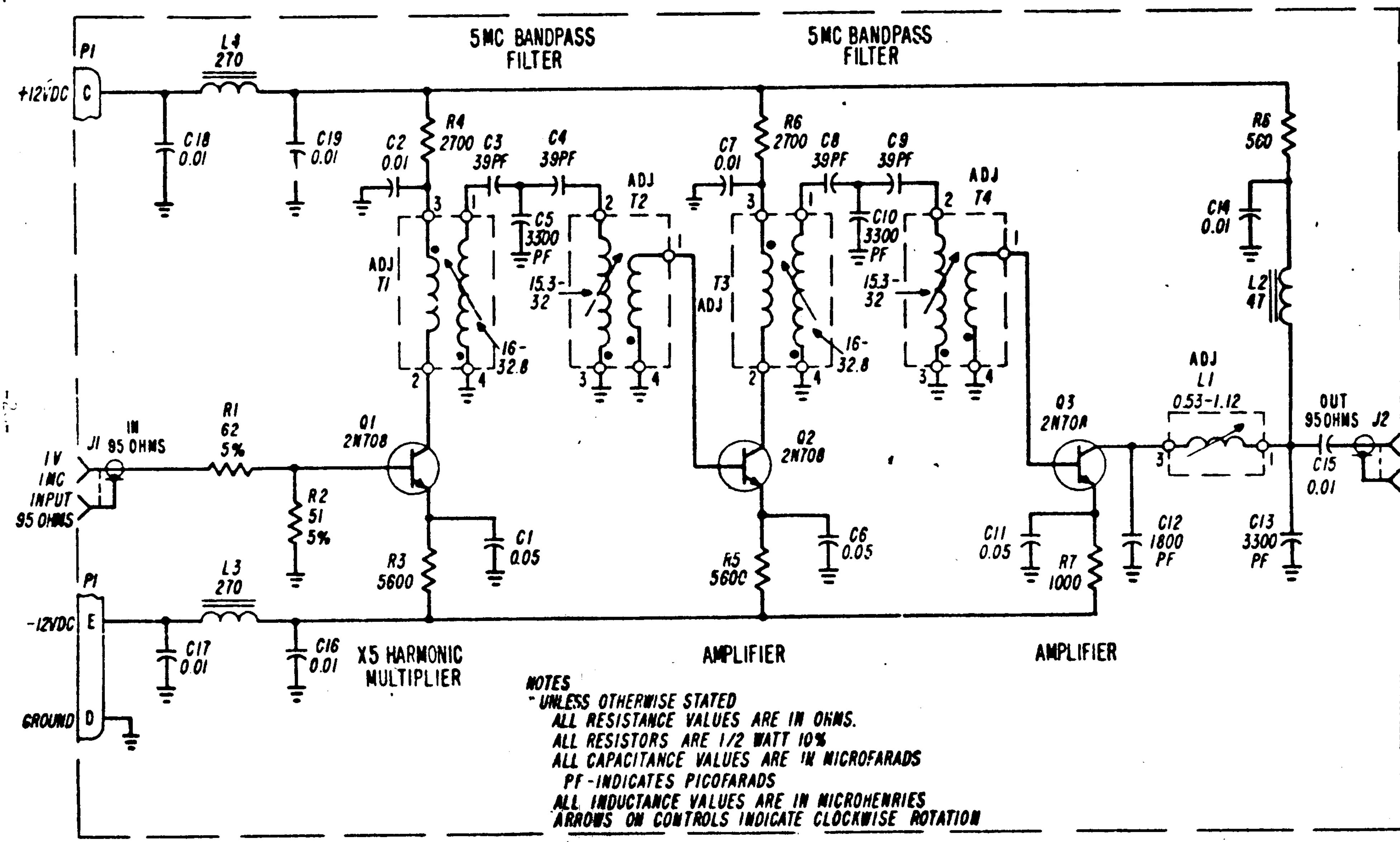
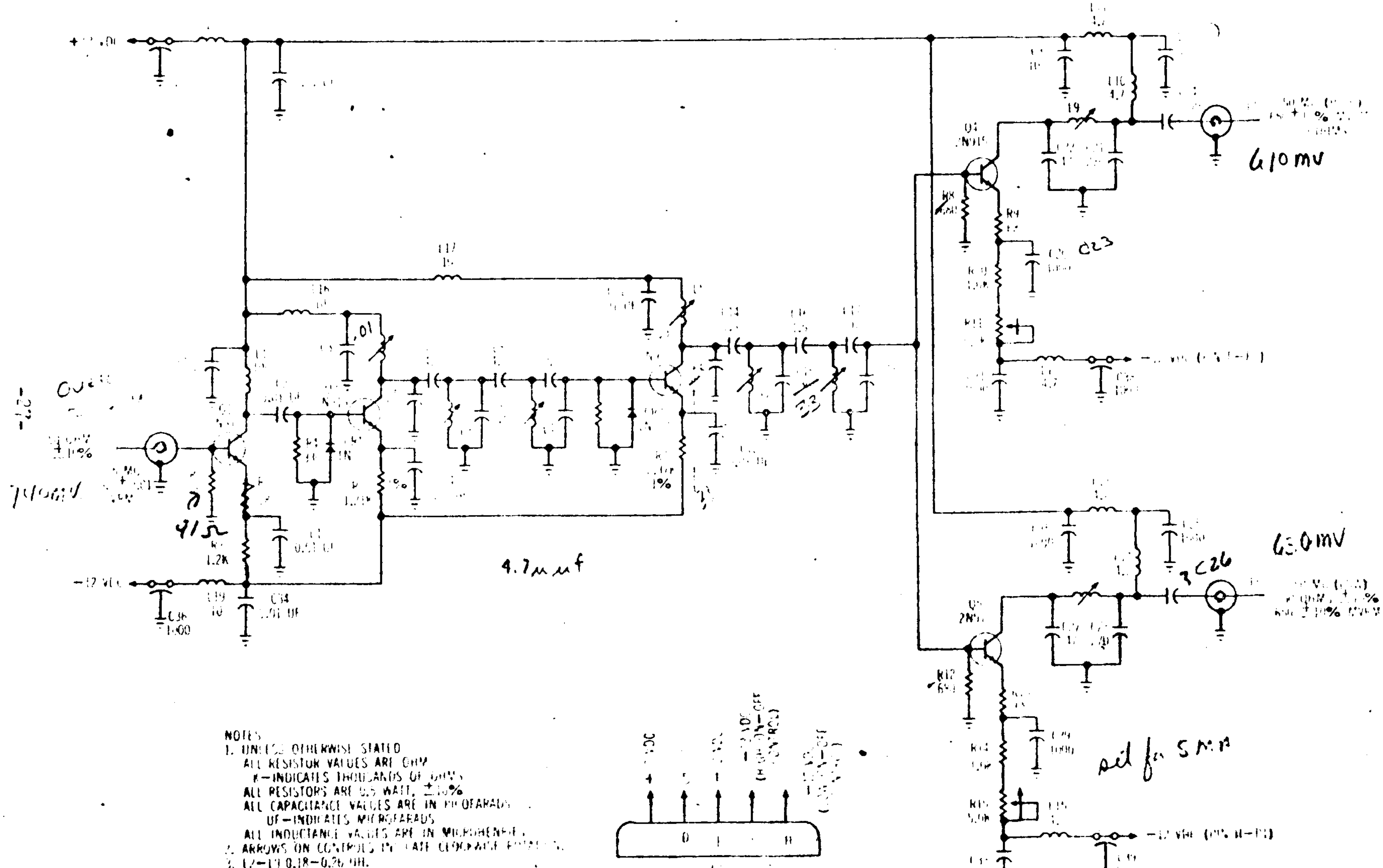


Figure 17. Schematic 1 to 5 MC Multiplier

467



NOTES

1. UNLESS OTHERWISE STATED
   - ALL RESISTOR VALUES ARE OHM
   - K—INDICATES THOUSANDS OF OHMS
   - ALL RESISTORS ARE 0.5 WATT, ±10%
   - ALL CAPACITANCE VALUES ARE IN PICOFARADS
   - UF—INDICATES MICROFARADS
   - ALL INDUCTANCE VALUES ARE IN MICROHENRIES
2. ARROWS ON CONTROLS INDICATE CLOCKWISE ROTATION
3. L7–L9 0.18–0.26 UH.

Figure 18. Schematic 5 to 50 MC Multiplier

FREQUENCY (MC)	db DOWN
1 MC	90 db
2	80
3	81
4	90
5	0
6	90
7	90
8	90
9	90
10	65
15	90
20	90
25	90

Table II. 1 to 5 MC Multiplier Spurious Levels

FREQUENCY (MC)	db DOWN
20	65
25	70
30	65
35	77
40	68
45	70
49	80
50	0
51.5	69
55	65
60	80
75	80
100	55
135	70

Table III. 5 to 50 MC Multiplier Spurious Levels

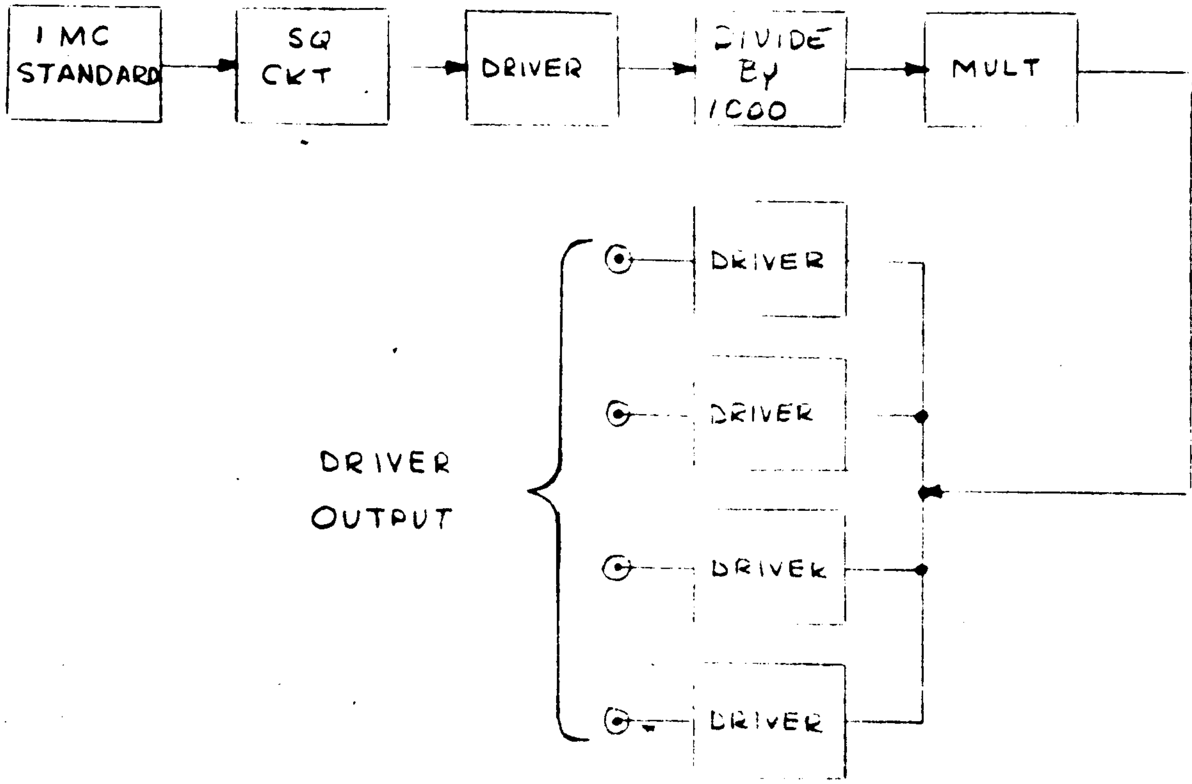


Figure 19. Digital Divider Block Diagram

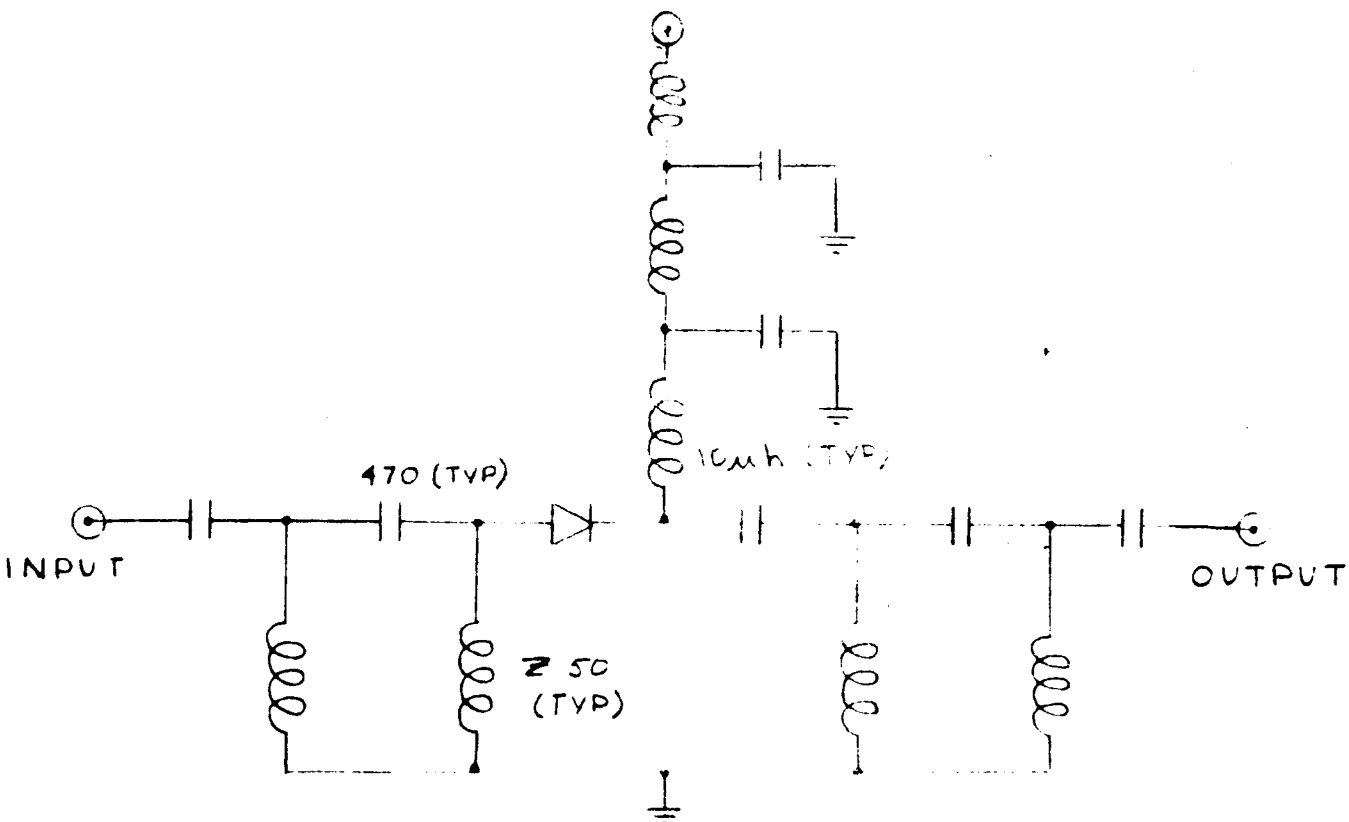


Figure 20. Schematic Dio[illegible]ter

VI. POWER MONITOR

Several techniques of power monitoring with feedback control for accurate power level control in the Linear S/N Summer were investigated. It was decided for versatility and high resolution that the Weinschel Engineering dual channel null detection system would be used. This system with modification offered good stability, drift free gain, an accuracy of .02db/10db with resolution capability of .001db and the flexibility of use in recalibration of the precision noise attenuator and signal attenuator.

This system shown in Figure 21 is basically an audio system with synchronous null detection. Noise power sampled from the noise channel through a 15db coupler is chopped at a 1000 cps rate thus producing a 1000 cps signal at the output of the bolometer. The detected 1000 cps signal is then applied to an adjustable 2 to 104db precision audio attenuator network and a low noise narrow band (30 cps bandwidth) 1000 cps tuned amplifier with a gain of approximately 130db adjustable over an 80db range. It is then compared with a reference 1000 cps signal in a synchronous null detector. The reference signal is the 50 MC signal derived from the 1 MC standard and sampled from the signal channel is the same manner as the noise signal. The reference signal like the noise signal is amplified in a narrow band, high gain (approximately 80db-voltage gain) 1000 cps tuned amplifior and fed to the synchronous null detector to be compared with the noise signal.

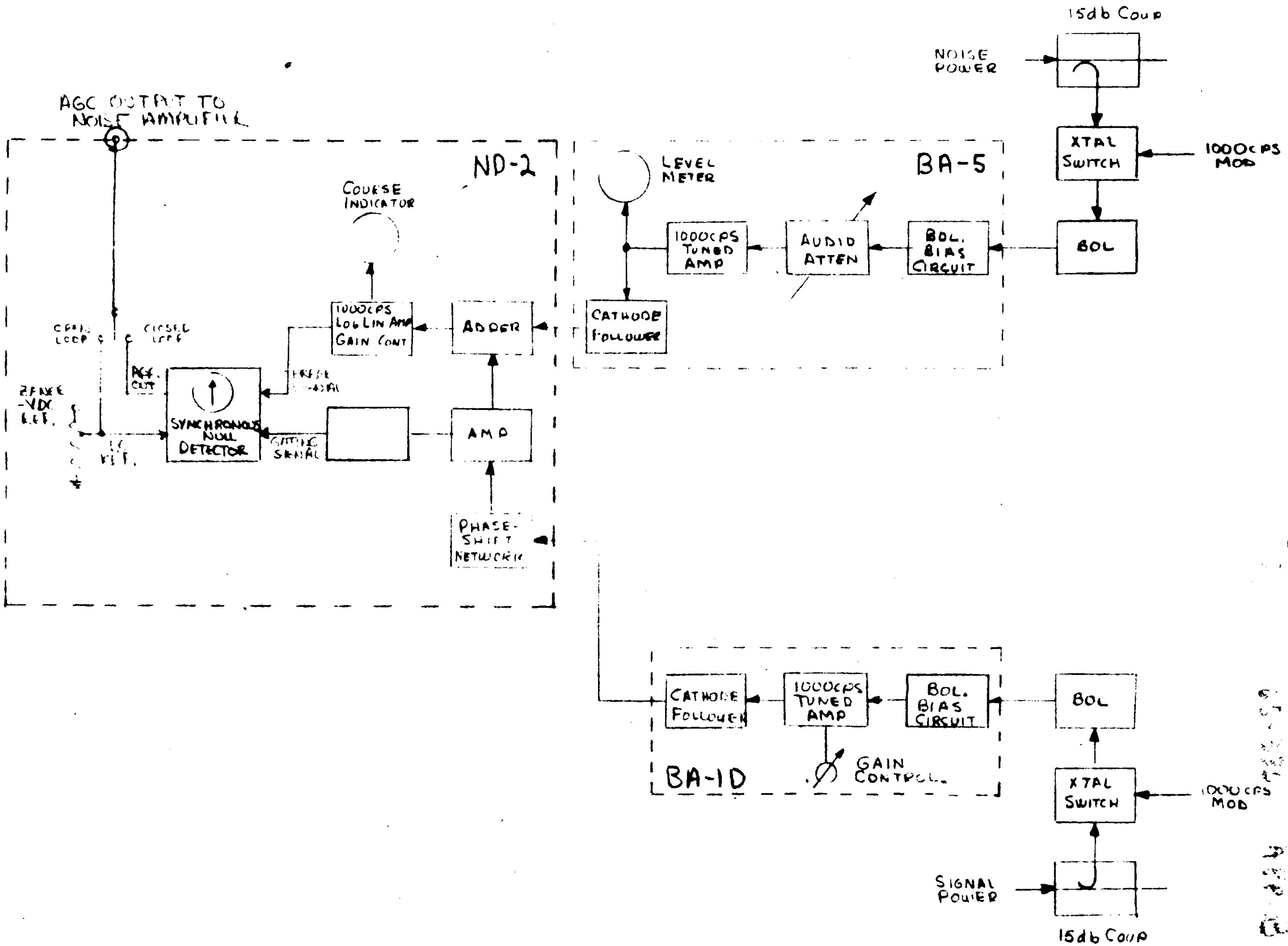
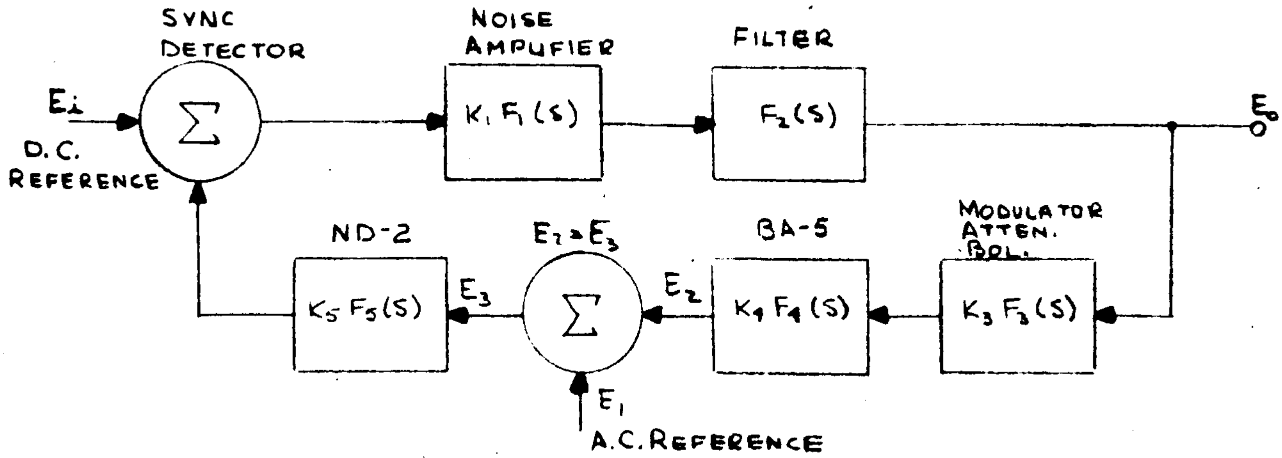

15db Coup
NOISE POWER
XTAL SWITCH
1000cps MOD
BOL
BA-5
LEVEL METER
1000cps TUNED AMP
AUDIO ATTEN
BOL. BIAS CIRCUIT
CATHODE FOLLOWER
AGC OUTPUT TO NOISE AMPLIFIER
ND-2
COURSE INDICATOR
1000cps Log Lin Amp Gain Cont
ADDER
OPEN LOOP
CLOSED LOOP
AGC OUT
SYNCHRONOUS NULL DETECTOR
AMP
PHASE-SHIFT NETWORK
CATHODE FOLLOWER
1000cps TUNED AMP
BOL. BIAS CIRCUIT
BOL
BA-1D
GAIN CONTROL
XTAL SWITCH
1000cps MOD
SIGNAL POWER
15db Coup

Fig. 21 [illegible]

The synchronous null detector provides an output about some pre-established operating voltage when the amplitudes of the noise signal and reference signal are first balanced and then there is a change in the ratio of the two signals. The reference signal is applied to a constant amplitude phase shifting network with a phase shifting capability at 1000 cps of over 360° essentially without a change in amplitude. Vectorial comparison of the reference signal and noise signal is made by an adder circuit. From the adder output, the signal is fed to the lin-log amplifier whose gain decreases logarithmically as the unbalanced amplitude increases providing maximum sensitivity at small amplitude differences. The output of the lin-log amplifier is applied to the control grid of the synchronous detector. A second signal taken from the output of the phase shifting network is applied through a limiter and a square wave shaping circuit to the deflection plates of the synchronous detector. The synchronous detector is powered through a floating power supply and referenced to ground through the feedback zener reference voltage.

An analysis of the power monitor feedback control loop was made and it was found that the loop was unstable at low gain settings and also the gain of the feedback loop was greatly attenuated when the loop was closed. A block diagram of the feedback loop with several of the components lumped into a single block is shown in Figure 22*. From

*K1F1 (s) is the transfer function of the noise amplifier, F2(s) the noise filter. K3F3(s) is the combined transfer of the modulator, attenuator and bolometer, K4F4(s) the PA-5 and K5F5(s) the ND-2. This block diagram shows two summing points to represent the reference of the noise channel to the signal channel. In analysis of the loop this AC reference can be assumed to be fixed and constant and therefore a transfer of one.



$$\frac{E_o}{E_i} = \frac{K_1 F_1 F_2}{(1 + K_1 K_3 K_4 K_5 F_1 F_2 F_3 F_4 F_5)}$$

Figure 22. Feedback Loop Block Diagram

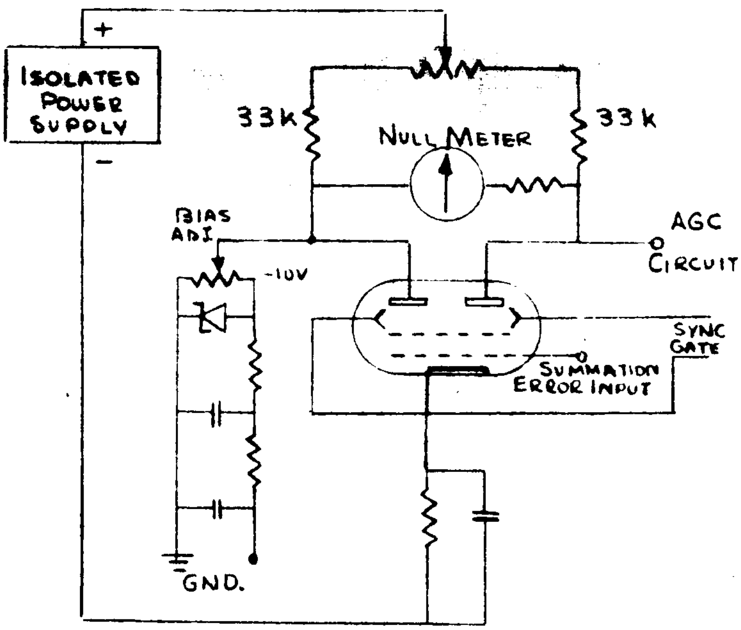


Figure 23. Synchronous Detector

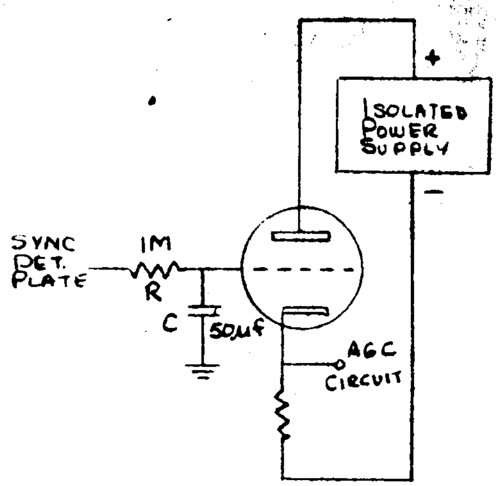


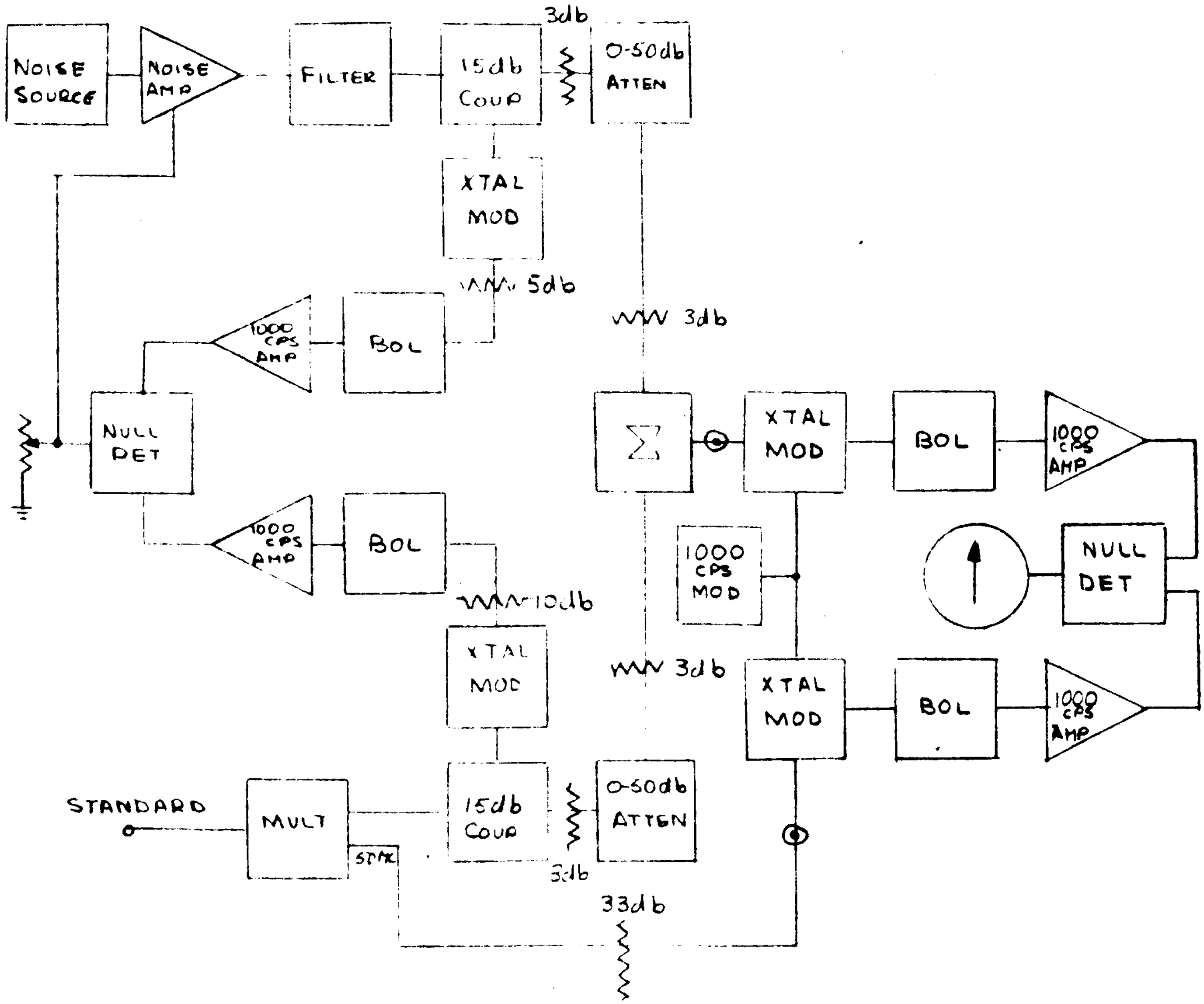
Figure 24. Synchronous Detector with RC Network

the closed loop transfer function, a Bode Diagram was constructed. After translation at the synchronous detector the only corners which influence the loop stability are contributed by the BA-5 1000 cps narrow band amplifiers. This amplifier has two twin tee filters each of which have second order poles centered at 1000 cps with bandwidths of 30 cps or 188.4 rad./sec. This was verified by observing the frequency at which the loop oscillated. The instability of the loop was corrected through the addition of a simple RC lag network with a time constant of .02 radian/sec.

The attenuation of the feedback gain was due to the loading of the synchronous detector in the closed loop operation. The synchronous detector (Figure 23) is a dual plate gated beam pentode which is powered through a floating power supply and is referenced to ground through the low impedance D.C. reference voltage which is adjusted at one of the plates. In closed loop operation, the other plate is connected to the AGC circuit in the noise amplifier. This also is a low impedance circuit which, when switched in, puts a low impedance between the two plates of the detector. The resulting loading lowered the open loop gain. This problem was solved by connecting an impedance matching cathode follower between the plate of the synchronous detector and the AGC circuit. The addition of the cathode follower had a second advantage in that the .02 rad./sec. lag network was placed at the grid of the cathode follower and a higher value resistance was realizable. This is shown in Figure 24. This was a problem because it is necessary to deliver 0 to 4 ma of drive current for the AGC network.

With the added network, the open loop gain measured 46db, with a gain margin of 20db. The performance of the feedback control loop with respect to drift, stability and correction of noise level changes was measured using the dual channel system at the output of the summer shown in Figure 25. This dual channel measuring system derived its reference signal from the 50 MC standard thereby referencing both the feedback control system and measuring system to a common source. The system was initially calibrated by first establishing a reference level at the summer output derived solely from the signal channel (noise channel attenuated) with the system operating in open loop operation. Then with the signal channel attenuated, the AGC voltage on the Noise Amplifier is adjusted to make the power level in the noise channel equal to the same reference level established by the signal channel. With the noise level adjusted to the signal level as described above, the 1000 cps attenuators in the feedback circuit were adjusted for a null and the loop was closed. The feedback loop then automatically adjusted for power level changes in the noise channel about the AGC voltage level established in open loop operation.

With the loop closed, there is a .02db offset of the noise level from the original reference level. For a 1db change at the Noise Generator the output of the summer corrects to .01db of the original reference level. Over any short term period it was difficult to discern any drift of the noise channel with respect to the signal channel. The best that could be measured in long term drift was .005db. Any drift or amplitude instability in the signal level was automatically compensated


NOISE SOURCE
NOISE AMP
FILTER
15db COUP
3db
0-50db ATTEN
XTAL MOD
5db
1000 CPS AMP
BOL
3db
NULL DET
Σ
XTAL MOD
BOL
1000 CPS AMP
1000 CPS AMP
BOL
10db
1000 CPS MOD
NULL DET
XTAL MOD
3db
XTAL MOD
BOL
1000 CPS AMP
STANDARD
MULT
15db COUP
0-50db ATTEN
3db
STAK
33db

[illegible] Loop [illegible]

for in the noise level by the feedback control.

The temperature sensitivity of the bolometer in the feedback control circuit as a source of drift between the two channels was tested by placing the bolometers in an oven and varying the temperature from 35°C to 45°C to 55°C. The diagram of this test set-up is shown in Figure 26. The system was first run at room temperature by taking reading in the dual channel point by point from 40 MC through 60 MC and recording these as reference readings. The system was again run at the above temperatures and the deviation from the readings at room temperature was recorded. These readings are shown in Table IV. The overall bolometer sensitivity was within ± .02db over this temperature change.

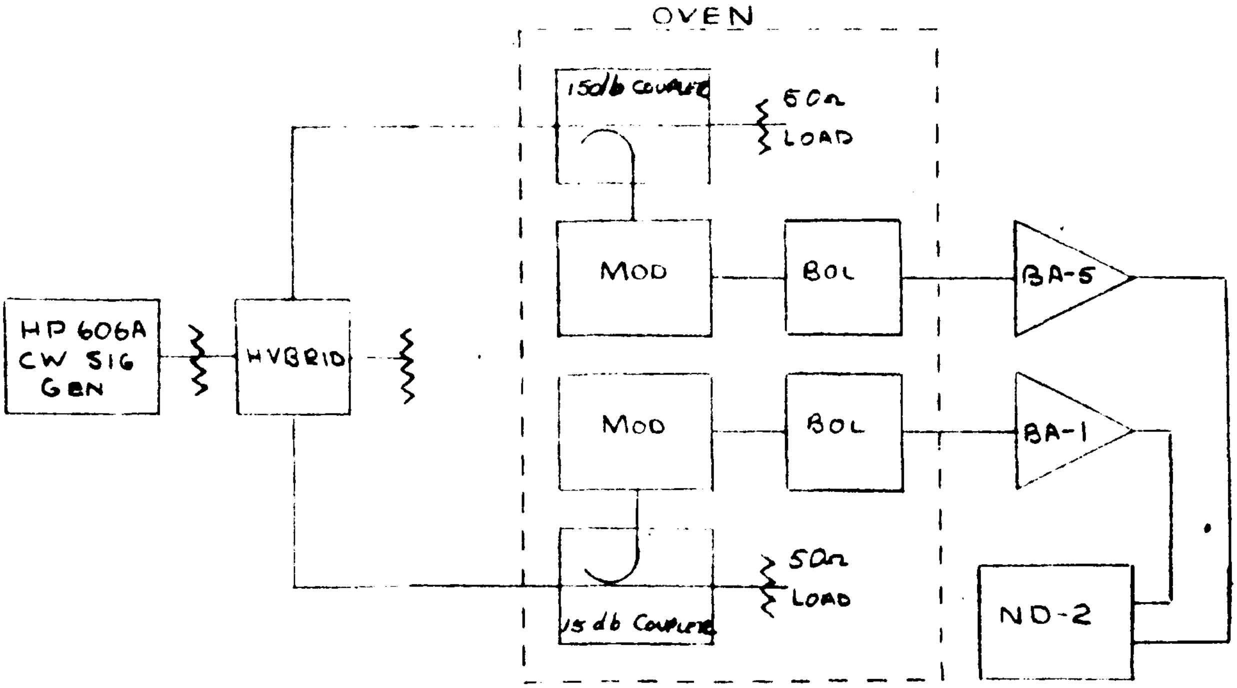


Figure 26. [illegible]

TEMP	DEVIATION IN DB FROM REFERENCE AT ROOM TEMP																	
	40	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	60
35°C	-.02	-.03	.00	.00	.00	.00	.00	+.01	+.01	.00	.00	.00	-.01	-.01	-.01	-.01	-.01	-.01	-.02
45°C	-.03	-.02	-.01	-.01	-.01	-.01	-.01	-.01	+.01	-.02	-.01	-.01	-.02	-.01	-.01	-.01	+.01	+.01	.00
55°C	-.01	-.02	-.01	-.01	-.02	-.02	-.02	-.01	.00	.00	.00	.00	-.01	.00	-.01	-.02	-.03	-.03	-.03

Table IV. [illegible]

VII. SYSTEM PERFORMANCE

The performance of the Linear S/N Summer was tested against the JPL specification No. GPG-150AZ-DSN paragraph 3.5.3. Test measurements were conducted in the following area; overall frequency response, intermodulation, linear summing, average S/N accuracy and S/N repeatibility.

Frequency response tests similar to those described in Section IV on the Noise Amplifier, were conducted on each of the components in the Linear Summer and then on the complete noise channel of the Summer. The result of this overall frequency response was identical to that of the Noise Amplifier/Filter Combination shown in Figure 13.

Two tone tests to determine the third order intermodulation products were conducted on the complete noise channel to determine if any of the other components besides the Noise Amplifier were introducing non-linearity. The results of this test are shown below in Table V.

Input Frequency f_1 = 50 MC at -5 dbm

Input Frequency f_2 = 53 MC at -5 dbm

$(2f_1 - f_2) = 47$ MC

Nominal Output -2 dbm

	50 MC	53 MC	47 MC
Nominal	-5 dbm	-5 dbm	30 db down
3db Above Nominal	-2 dbm	-2 dbm	30 db down
6db Above Nominal	+1 dbm	+1 dbm	26 db down

Table V. Noise Channel Intermodulation Test Results

Comparison of the third order intermodulation products of the noise channel with those of the Noise Amplifier show that the noise channel produces intermodulation products in the worst case (6db above nominal) is 6db higher than those of the Noise Amplifier alone. Even taking this extreme case yields at worst products in the order of 1/500 of the desired signal.

A verification test of the linear summing at the output of the S/N Summer is shown in Figure 27. The output of each channel was adjusted for equal power levels, then with the linear S/N summer operating in its normal operating condition of closed loop, each channel was separately varied using the precision attenuators and the change in output power was recorded. The change in power output was compared with the theoretical change to get a measure of the linear summing. These readings are shown in Table VI.

For the average S/N measurement, the linear S/N Summer was set up in its normal operating condition as shown in Figure 28. With the measurement system connected to the output of the summer as shown in Figure 28, the power level of each channel was adjusted such that at the output of the amplifier in the test set-up, the Signal Power P_s was 10db down from the Noise Power P_n. At the output of the summer itself, the Noise Power P_n is 20db greater than the Signal Power P_s because the bandwidth of the noise channel is 15 MC whereas the test amplifier bandwidth is approximately 1.5 MC. The resulting P_n and P_s at the test amplifier output was -10 dbm and -20 dbm respectively. All possible combinations of S/N Ratios with the above set-up are displayed in the

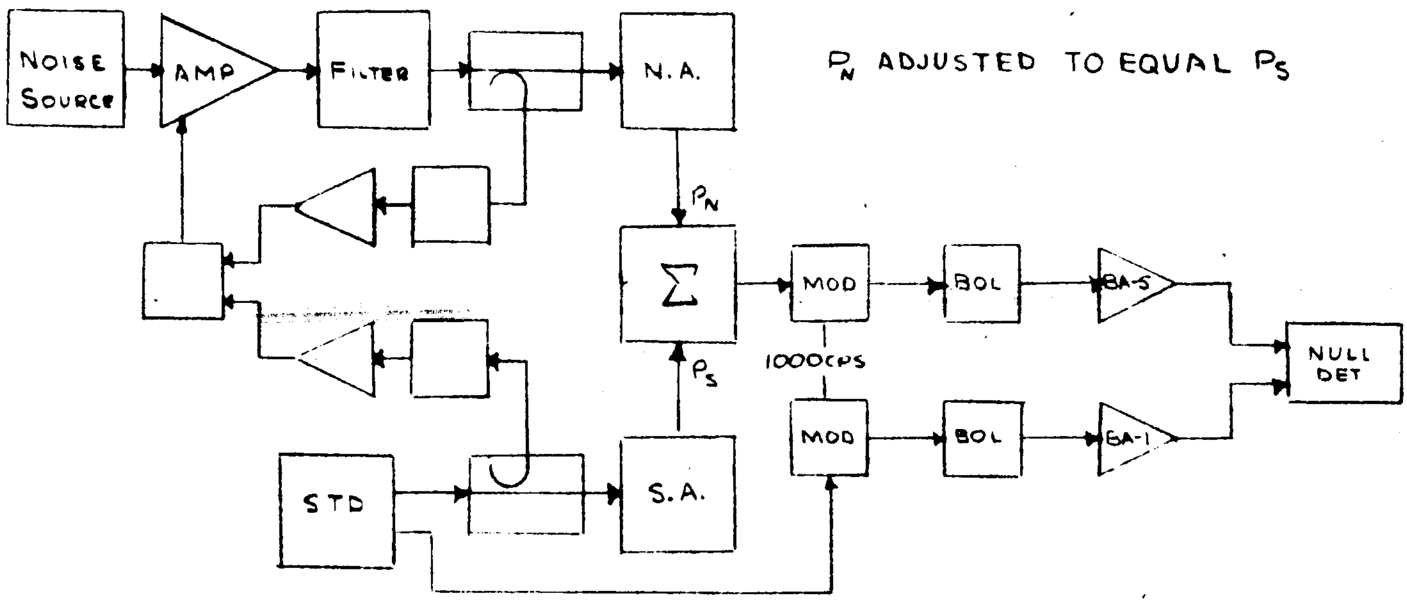


Figure 27. [illegible]

N.A Set at 0.00			
S.A	Theor. Change	Δdb	Error
0.00	Ref	—	—
1.00	.470	.460	-.010
2.00	.887	.870	-.017
3.00	1.246	1.240	-.006
5.00	1.815	1.800	-.015
10.00	2.596	2.565	-.031
20.00	2.967	2.930	-.037
50.00	3.010	2.970	-.040

S.A. Set at 0.00			
N.A.	Theor. Change	Δdb	Error
0.00	Ref	—	—
1.00	.470	.460	-.010
2.00	.887	.870	-.017
3.00	1.246	1.230	-.016
5.00	1.815	1.790	-.025
10.00	2.596	2.565	-.031
20.00	2.967	2.930	-.037
50.00	3.010	2.975	-.035

Reference : $P_N = P_S$

$$P_{REF} = P_N + P_S = 2P$$

$$\therefore P_{OUT} = 10 \log \frac{2P}{P_N + \Delta P_S} \quad \text{(For N.A Set at 0.00)}$$

$$P_{OUT} = 10 \log \frac{2P}{P_S + \Delta P_N} \quad \text{(For S.A. Set at 0.00)}$$

Table VI. [illegible]

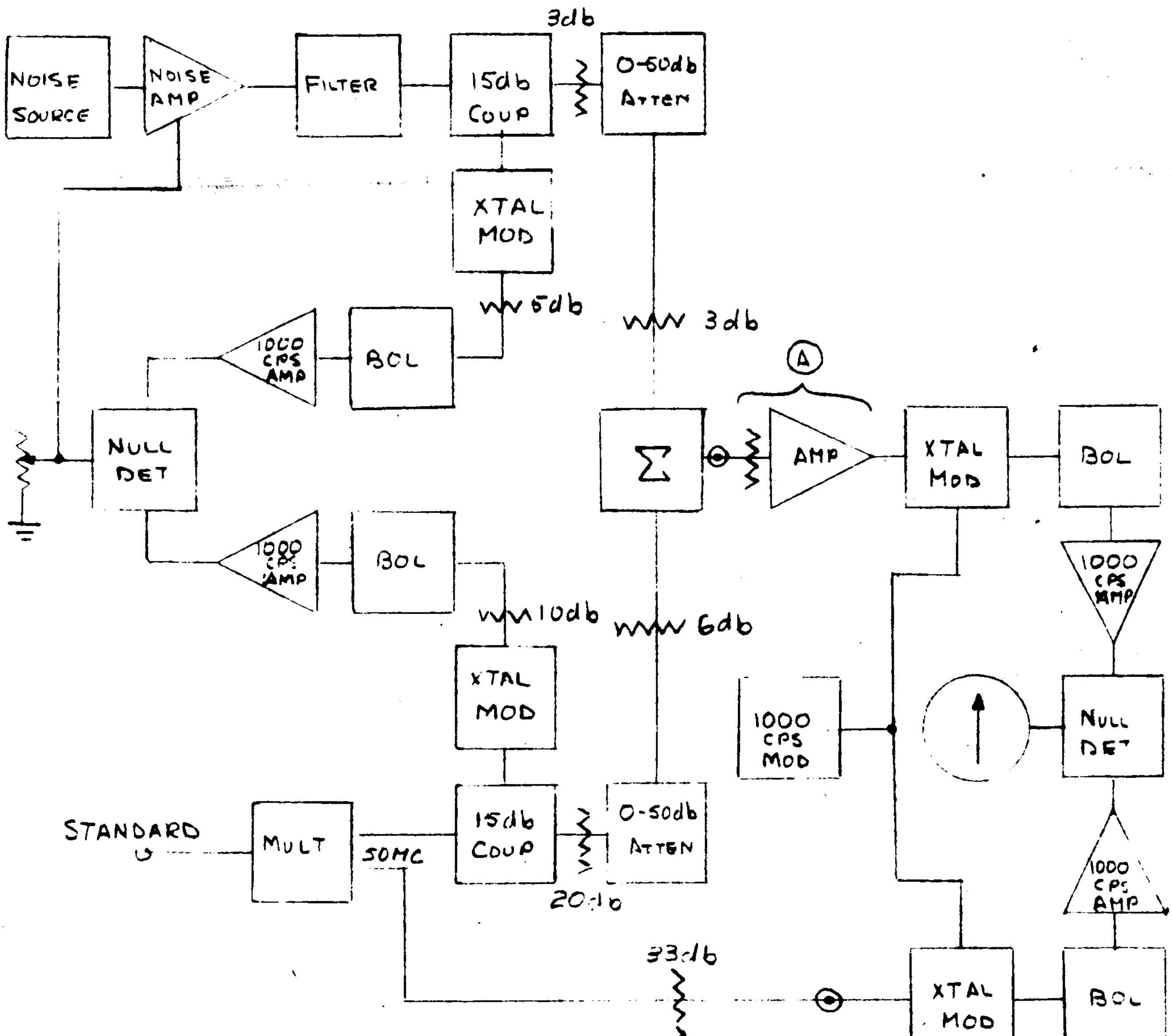


Figure 28. [illegible] S/N Measurement Test Set-Up

41

matrix shown in Table VII.

In the measurement set-up, the combination of the attenuator and amplifier A had the range of 0 to 30db of attenuation. That is, for A set at 30db, P_n = -10 dbm and P_s = -20 dbm; for A set at 0db, P_n = +20 dbm and P_s = +10 dbm. The matrix was divided into 4 quadrants such that; in quadrant I, A was set to 30db of attenuation; in quadrant II, A was set to 0 for the signal attenuator (SA) settings and 30db for the noise attenuator (NA) settings; in quadrant III, A was set to 0db for the NA settings and 30db for the SA settings, and finally; in quadrant IV, A was set to 0db for both the NA and the SA settings. In the above manner, it was possible to test every possible S/N setting.

With the range of 50db for each attenuator and the smallest increment of each of .1db, there are 500 possible settings on the NA and the SA or in combination 25 x 10^4 possible S/N settings. Since this was virtually impossible to test in total, random settings were generated in each quadrant and a total of 10 readings were taken from each quadrant plus the corner settings of each, i.e. 0.0 - 0.0, 0.0 - 50.0, 50.0 - 0.0 and 50.0 - 50.0.

From the results of these tests, the mean, variance, and standard deviation of each quadrant was calculated. These readings and calculations are shown in Table VIII. By comparison, each quadrant was found to be a sub-set of the total population, and a mean, variance and standard deviation was calculated for all the readings. From this mean and standard deviation a statement can be made 95% confidence that no more than 5% of the readings would fall outside of ± .156 db of the mean.

# P_N	S.A. / N.A.	-20dbm 0.0	0.1	0.2	① -45dbm ② -45dbm 24.8	24.9	25.0	① -45.1dbm ② -10dbm 25.1	25.2	25.3	49.8	49.9	-70dbm 50.0
① -10dbm ② -10dbm	0.0	-10.0	-10.1	-10.2	-34.8	-34.9	-35.0	-36.1	-36.2	-35.3	-59.8	-59.9	-60.0
	0.1	-9.9	-10	-10.1	-34.7	-34.8	-34.9	-35.0	-35.1	-35.2	-59.7	-59.8	-59.9
	0.2	-9.8	-9.9	-10	-34.6	-34.7	-34.8	-34.9	-35.0	-35.1	-59.6	-59.7	-59.8
		QUADRANT I						QUADRANT II					
① -35dbm ② -35dbm	24.9	+14.9	+14.8	+14.7	-9.9	-10	-10.1	-10.2	-10.3	-10.4	-34.9	-35.0	-35.1
	25.0	+15.0	+14.9	+14.8	-9.8	-9.9	-10	-10.1	-10.2	-10.3	-34.8	-34.9	-35.0
① -35.1dbm ② -5dbm	25.1	+15.1	+15.0	+14.9	-9.7	-9.8	-9.9	-10	-10.1	-10.2	-34.7	-34.8	-34.9
	25.2	+15.2	+15.1	+15.0	-9.6	-9.7	-9.8	-9.9	-10.0	-10.1	-34.6	-34.7	-34.8
	25.3	+15.3	+15.2	+15.1	-9.5	-9.6	-9.7	-9.8	-9.9	-10.0	-34.5	-34.6	-34.7
		QUADRANT III						QUADRANT IV					
① -60dbm ② -30dbm	49.8	+39.8	+39.7	+39.6	+15.0	+14.9	+14.8	+14.7	+14.6	+14.5	-10.0	-10.1	-10.2
	49.9	+39.9	+39.8	+39.7	+15.1	+15.0	+14.9	+14.8	+14.7	+14.6	-9.9	-10.0	-10.1
	50	+40.0	+39.9	+39.8	+15.2	+15.1	+15.0	+14.9	+14.8	+14.7	-9.8	-9.9	-10.0

* The power levels indicated at the beginning and end of the quodrants of the signal attenuator row and noise attenuator column are: (1) the power levels at the output of the summer referenced to the 1MC bandwidth of the amplifier A, and (2) the power levels into the bolometer.

Table VII. Matrix of Average S/N Reading

QUADRANT I					
NO.	S.A.	N.A.	S/N CALC	S/N MEAS	Δdb
1	.3	3.2	-7.1	-7.17	-.07
2	7.3	4.1	-13.2	-13.2	00
3	11.6	24.3	+2.7	+2.70	00
4	13.1	5.9	-17.2	-17.30	-.10
5	12.6	29.3	+6.7	+6.63	-.07
6	4.7	11.4	-3.3	-3.40	-.10
7	13.7	26.1	+2.4	+2.32	-.08
8	16.5	22.2	-4.3	-4.27	+.03
9	13.4	27.6	+4.2	+4.07	-.13
10	8.3	19.9	+1.6	+1.56	-.04
CORNER	0.0	0.0	-10.0	-9.91	+.09
$n = 11$			$\bar{X} = -.043$ db		
$V = .00434$			$\sigma = .0659$		

QUADRANT II					
NO.	S.A.	N.A.	S/N CALC	S/N MEAS	Δdb
1	38.4	28.4	-20	-20.05	-.05
2	49.5	24.3	-35.3	-36.28	+.02
3	29.7	29.3	-10.4	-10.44	-.04
4	23.9	7.8	-26.1	-26.19	-.09
5	21.8	22.9	-8.9	-8.97	-.07
6	39.0	24.0	-25.0	-25.09	-.09
7	45.2	28.0	-27.2	-27.12	+.08
8	39.7	20.8	-28.9	-28.98	-.08
9	48.0	0.9	-67.1	-56.94	+.07
10	45.7	29.6	-26.1	-26.12	-.02
CORNER	50.0	0.0	-60.0	-60.01	-.01
$n = 11$			$\bar{X} = -.0254$ db		
$V = .00373$			$\sigma = .0611$		

QUADRANT III					
NO.	S.A.	N.A.	S/N CALC	S/N MEAS	Δdb
1	10.1	36.5	+16.4	+16.35	-.05
2	1.9	32.1	+20.2	+20.19	-.01
3	18.8	39.9	+11.1	+11.06	-.04
4	14.9	40.6	+15.7	+15.63	-.07
5	9.6	47.2	+27.6	+27.66	-.04
6	12.5	33.2	+10.7	+10.65	-.05
7	7.5	30.3	+12.8	+12.74	-.06
8	19.3	31.6	+2.3	+2.29	-.01
9	11.9	30.9	+9.0	+9.0	.00
10	1.3	43.1	+31.8	+31.89	+.09
CORNER	0.0	50.0	+40	40.05	+.05
$n = 11$			$\bar{X} = -.0173$ db		
$V = .00242$			$\sigma = .0492$		

QUADRANT IV					
NO.	S.A.	N.A.	S/N CALC	S/N MEAS	Δdb
1	35.2	34.8	-10.40	-10.50	-.10
2	21.2	48.0	+16.80	+16.87	+.03
3	29.9	45.1	+5.20	-5.22	+.02
4	36.9	44.0	-2.40	-2.34	+.06
5	44.7	31.8	-22.9	-22.86	+.04
6	37.3	31.7	-15.60	-15.66	-.06
7	45.0	38.4	-16.60	-16.70	-.10
8	30.3	33.7	-6.60	-6.72	-.12
9	35.6	36.0	-9.60	-9.74	-.14
10	30.2	36.1	-4.10	-4.25	-.15
11	36.3	38.8	-6.50	-6.60	-.10
CORNER	50.0	60.0	-10.0	-10.05	+.05
$n = 12$			$\bar{X} = -.0475$		
$V = .00654$			$\sigma = .0809$		

Table VIII. Average S/N Measurements and Calculations

$$N = 45 \text{ Readings}$$

$$\Sigma X_i = 1.51$$

$$\bar{X} = -.0336\text{db}$$

$$(1 - N)V = \sum_{i=1}^{N} X_i^2 - N\bar{X}^2$$

$$V = .0042$$

$$\sigma = .065$$

Therefore with 95% confidence that 95% of the readings fall within the limits:

$$\bar{X} - K\,(.065) < X < \bar{X} + K\,(.065)$$

$$-.034 - (2.41)(.065) < X < -.034 + (2.41)(.065)$$

$$-\ .190\text{db} < X < +\ .123\text{db}$$

The repeatability was tested by selecting eight S/N settings which utilized as many of the attenuators inside the precision attenuators (NA and SA) and repeating these S/N settings continually at a random rate over a four hour period. By using only eight S/N settings, it was possible to repeat each setting thirteen times for a total of 104 readings. In order to cover a wider range on both the NA and SA, the 20db pad was removed from the signal channel such that the signal level equalled the noise at the output of the summer when both the SA and NA were set at the same setting. In order to eliminate as much drift and instability in the test equipment, the test amplifier was removed and the readings were made at the noise bandwidths of 15 MC with a test set-up similar to that of Figure 28.

The data compiled for this measurement is shown in Table IX. The largest difference in readings for any one setting was .023db. This data was analyzed and the mean, and standard deviation for each of the eight readings was computed. The 95% confidence level at 5% tolerance limits was applied to each of these settings to get a measure of S/N setting repeatability. In the worst case it can be stated with 95% confidence that no more than 5% of the readings would repeat outside ± .024db. The calculations of the mean, standard deviation and 5% tolerance limits are shown at the right of Table IX.

Each group of the eight S/N settings was treated as a subset of the total readings. A mean and standard deviation was computed for each of these subsets. These calculations are shown at the bottom of Table IX. The off-set of the mean for each of the set of readings was found to be an error in the setting up of the initial conditions. That is in setting the signal power equal to the noise power by first setting a reference level in the measurement system from one of the channels and then duplicating this reference from the other channel. The problem appeared to be distortion introduced by the 1000 cps modulator for when the two channels were balanced using a power meter, a different mean was achieved. This was a static off-set which created no problem other than operating about some value other than zero. The relation between S/N settings was the unchanged for different off-sets.

The change in the means of the 13 sets of S/N readings over the 4 hour measurement period is a measure of the drift of the Linear S/N Summer plus the measurement system. The mean of these 13 means is .0054db

65-335
APP. B

Signal Atten	Noise Atten	S/N BW = 15mc	Deviation From Calculated S/N Settings (DB) 1	2	3	4	5	6	7	8	9	10	11	12	13	Largest Spread	Mean $\bar{X}$	Std Dev σ	5% Tol
7.3	4.1	-3.20db	-.005	0.000	-.010	0.000	-.005	-.010	-.010	-.015	-.012	-.014	+.001	0.000	-.007	0.016db	.0067	.0056	±.012db
8.0	18.2	+10.20	-.055	-.050	-.065	-.060	-.065	-.070	-.060	-.064	-.069	-.073	-.058	-.063	-.068	.023	.0631	.0064	±.020
13.1	5.9	-7.20	-.040	-.040	-.040	-.045	-.040	-.040	-.050	-.055	-.055	-.043	-.033	-.045	-.033	.022	.0430	.0070	±.022
7.1	19.9	+12.80	-.080	-.075	-.095	-.095	-.090	-.090	-.080	-.096	-.098	-.090	-.083	-.090	-.097	.023	.0887	.0075	±.024
19.2	14.5	-4.70	-.040	-.035	-.035	-.045	-.040	-.050	-.050	-.045	-.045	-.036	-.036	-.045	-.042	.015	.0418	.0053	±.017
15.0	13.2	-1.80	-.065	-.060	-.065	-.060	-.055	-.065	-.066	-.073	-.070	-.054	-.065	-.067	-.062	.019	.0636	.0059	±.017
4.5	11.4	+6.90	-.090	-.080	-.085	-.095	-.090	-.095	-.087	-.098	-.099	-.083	-.078	-.090	-.084	.021	.0888	.0067	±.021
0.3	3.2	+2.90	-.040	-.045	-.045	-.050	-.050	-.050	-.048	-.050	-.050	-.044	-.047	-.054	-.045	.014	.0475	.0037	±.011
		Mean $\bar{X}$	.0519	.0481	.0538	.0563	.0544	.0588	.0569	.0620	.0623	.0546	.0499	.0568	.0547				
		Std Dev σ	.0269	.0252	.0260	.0304	.0281	.0276	.02361	.0317	.0287	.0257	.0247	.0289	.0289				

Table IX. S/N Repeatability Over Four Hour Period with a variance of 1.717×10^{-5} and a standard deviation of .004. From this data it can then be stated that with 95% confidence and 5% tolerance limits, the system would not drift more than $\pm$ .013db. This figure includes the drift of the measurement system and is well within the specification requirement of $\pm$ 0.1db/4 hour period for the signal power and $\pm$ 0.1db/1 hour period for the noise power.

65.335
APP. B

VIII. CONCLUSION

The test results of the Linear S/N Summer satisfy all of the specification requirements outlined in paragraph 3.5.3 of the JPL Specification GPG-15062-DSN. Using random sampling techniques, 40 S/N Measurements from a population of 250,000 S/N settings were made and found to be accurate within ± .155db. The specification calls for ± .3db over this 100db dynamic range. Repeatability over a four hour period was measured to be between .011 and .024db. The overall drift of the Linear S/N Summer is ± .013db compared with the specification of ± 0.1db each, for the noise source, the signal source and the power monitor.

The frequency response of the noise channel was measured at room temperature to be flat within ± .05db from 44.6 to 53.6 MC. The noise power spectral over this frequency range will be measured as a separate test and is not part of this report.